JPRS-USP-85-003

4 March 1985

USSR Report

SPACE

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USSR REPORT

SPACE

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HOLOGRAPHY IN SPACE

Moscow ZEMLYA I VSELENNAYA in Russian No 3, May-Jun 84 pp 17-24

[Article by V. M. Tuchkevich, academician, Yu. P. Semenov, doctor of technical sciences, and S. B. Gurevich, doctor of physical and mathematical sciences]

[Text] The unusual nature of man's activity in space requires both new instrumentation and methods for its use. Holography has now occupied a special place among them.

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Possibilities of Holography

Holography is a method for obtaining an image of any object and is based on the interference of light waves. A second "reference" wave is directed from the same light source (laser) as an "object" wave, reflected by the object, onto a photoplate (or photographic film). The interference of these waves, registered on a light-sensitive surface, gives a pattern which contains complete information on the object. This is a hologram. Later, by irradiating the hologram or some parts of it with a reference wave, it is possible to see three-dimensional image of the object of interest.

Employing holographic techniques and light-sensitive materials, it is possible, as in photography, where lens optics is used, to register and for a long time to retain light information on the object in order to reproduce its image later when the need for this arises. In a certain sense holography is similar to photography; they have one and the same object. Photography long ago became a necessary component of most experiments and practical applications. Why then is photography alone not adequate? After all, its techniques are already well developed.

The fact is that the image obtained by the holographic method is far more informative. In holography the wave front of light emanating from an object is registered and then retrieved; in photography there is only a plane image formed by lenses. Accordingly, holographic methods make it possible to recreate a three-dimensional image, which is completely unattainable for photography. And indeed, sometimes it is extremely necessary to see an object and the space surrounding it three-dimensionally, for example, during the landing of an aircraft or the docking of spaceships. However, this is not the only advantage of holography. It makes it possible to observe a transparent medium and to determine the changes transpiring in it (phase inhomogeneities), which cannot be distinguished by the human eye and which are not registered in ordinary photography.

A special feature of the new method is that it is possible to make several records on one and the same sector of photosensitive materials and then separately retrieve each registered wave front, thereby registering the information more densely and making it possible to compare the interferometric patterns from the objects at different moments in time.

There are also many other advantages of holography over photography. And nevertheless it has not, for the time being, been displaced. This is impeded by the need to use an artificial light source, whereas under ordinary conditions objects most frequently are illuminated by natural sunlight. A major difficulty is the costliness of the holographic equipment itself, as well as the rigidity of the conditions under which the survey is made and the need for qualified specialists, all this limiting the use of holography. It is true that as the equipment is improved the obstacles associated with its servicing are now being successfully overcome.

The merits of holography also determine those regions where it can be employed most effectively. These include graphic holography (obtaining three-dimensional images by the holographi method), used for practical and technical purposes, such as in museum work, in the construction of training apparatus. The method has found use in holographic microscopy, holographic interferometry, which makes it possible, for example, to study changes in the phase structure of transparent substances, deformations of objects, the nature of their vibration in apparatus for nondestructive monitoring, recognition of images and their processing. Holography is used in measuring the size and distribution of particles, in obtaining hologram optical elements, in holographic memory systems and in many other fields.

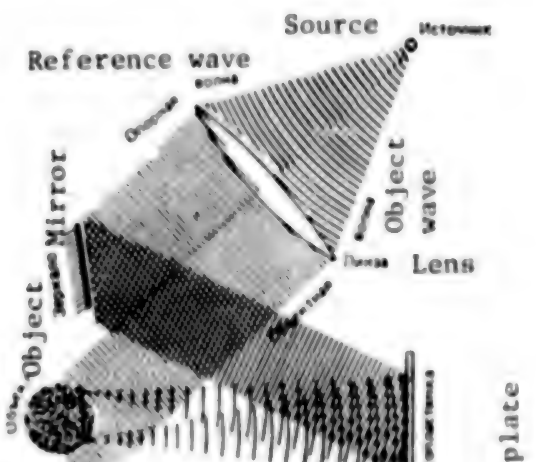


Diagram of registry of hologram of object diffusely scattering light. The interference pattern is formed by the superposing of a reference wave front on object wave fronts from a set of object points. This interference pattern is registered on a photoplate which after development is the hologram itself.

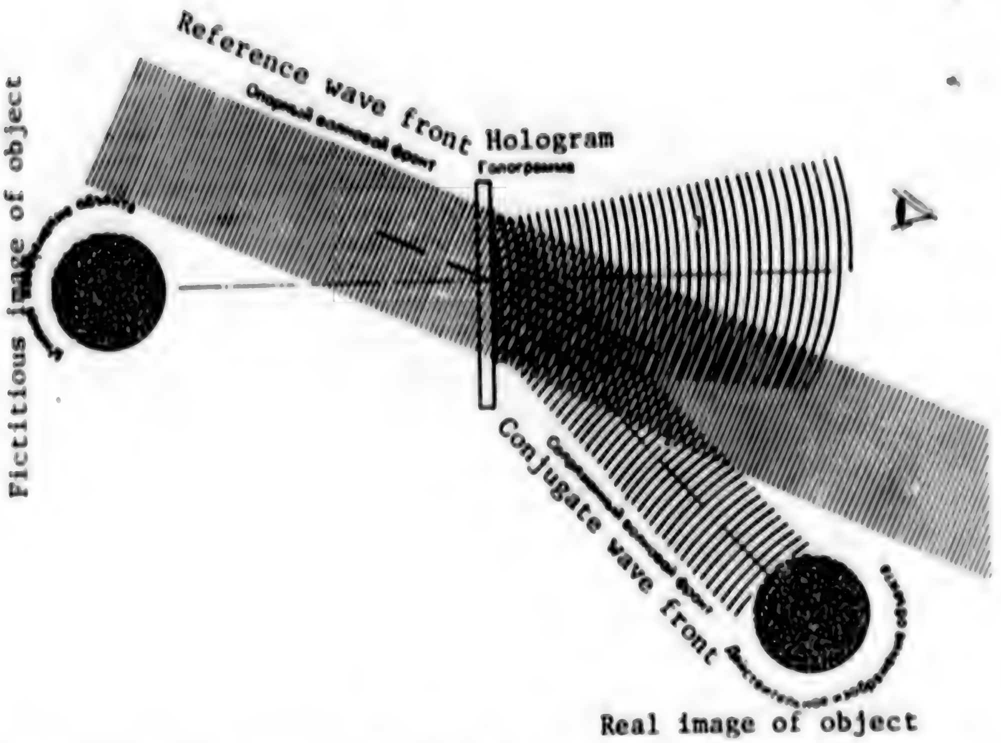


Diagram of retrieval of wave front from hologram (the elements of the interference pattern constitute the sum of the superposed diffraction gratings). The reference wave front, similar to the wave front during registry and oriented in the same way, is incident on the hologram. Deflecting the rays, the hologram forms waves 1 and 2, similar to those which emanated from the object. This makes it possible to see the fictitious and real images of the object.

Holographic Apparatus for Space

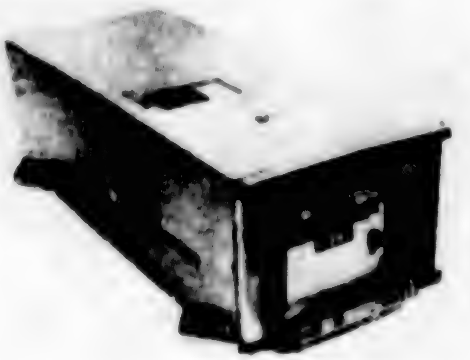
The first space holographic experiment, prepared by scientists of the USSR and Cuba, was carried out on 27 March 1981 by the international Soviet-Mongolian crew of the "Salyut-6"-"Soyuz T-4"-"Soyuz-39" crew. In a communication on the results of the work of this crew it was noted: "An important part of the flight program was experiments for testing new methods for the registry and transmission of holographic images of objects for the solution of different scientific and technical 'ems in space."

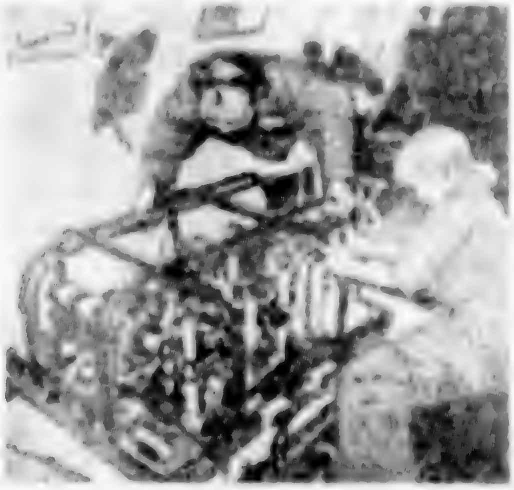
The development of hologr apparatus for space was a difficult task. As already mentioned, laborator ographic apparatus is complex, heavy and at all times requires the taking of measures for safeguarding it against the influence of vibration. This is not to say that such apparatus is not suited for space. But there is a need for apparatus which will not be destroyed during launching, will not lose its operability and will not go out of adjustment during transport in orbit. At the same time, it must have minimum mass and volume, not require complex adjustments, be simple to control, reliable in operation and require a minimum of power.

In the USSR and in the United States work began on the development of holographic apparatus for space stations and ships meeting the formulated requirements, but in their development work scientists proceeded on the basis of

different principles. Soviet specialists did away with the traditional plane placement of components of the holographic apparatus on benches and plates and placed them in a space, coupling them to a framework resistant to vibration. Nothing similar has been developed elsewhere. For example, the holographic apparatus designed in the United States and tested in 1982 (after the holographic experiment aboard the "Salyut-6" station) in an aircraft flying in a parabolic trajectory is of the traditional design. It has the plate-type base characteristic for laboratory apparatus and a volume and mass considerably greater than for the Soviet apparatus.

The space holographic apparatus developed by specialists of the Physical Technical Institute imeni A. F. Ioffe, USSR Academy of Sciences, consisted of the main instrument and removable attachments. The inner design of the main KGA-1 instrument operating aboard the "Salyut-6" station differed somewhat from the KGA-2 which was carried on the "Salyut-7" station. Both apparatuses included the Soviet LG-78 helium-neon laser. The instruments measured 450 x 210 x 120 mm, the weight was not more than 5 kg, the consumed power was less than 60 W and the exposure of the object (depending on the optical system used) was from fractions of a second to tens of seconds. The photosensitive material was Soviet holographic photoplates and photographic film.





KGA-2 holograph.
Space holograph developed in USA.

The initial optical system for the instrument corresponded to a holographic system with an extra-axial reference beam. The recorder was an attachment in the form of the body of a "Zorkiy-4" camera without an objective, loaded with holographic photographic film. The camera was adapted for a regime in which one or two exposures could be made (spaced in time). In the first case a hologram of the object was obtained; in the second case, with restitution, an interferogram was obtained which revealed a change in the object with the course of time.

When working with the KGA-1 use was made of a special optical attachment which allowed this same instrument to be adjusted (by covering the extra-axial reference beam) for holographic registry with a counter reference beam by the method proposed by Yu. N. Denisyuk, corresponding member, USSR Academy of Sciences. In this case the hologram was registered on a holographic photoplate.

A third variant was used in the KGA-2 instrument and was developed for the "Tavriya" experiment. The KGA-2, in contrast to the KGA-1, had a greater holographic volume and its optical system included a glass plate making it possible to create a carrier frequency of the interference bands and a frosted glass was placed behind the object (in case of necessity it could be removed). The first attachment to this instrument was a recording device: a series of holograms with double exposure and with a change in time between the first (it was the same for all the holograms) and the second exposures appeared on the plate. This made it possible to study the dynamics of the investigated process.

In the fourth variant the KGA-2 was also employed, but with a different optical attachment, making it possible to investigate processes in real time. A hologram of the initial state of the object was exposed on a plate used in this attachment. Then the plate was developed and holograms of subsequent states were observed through it. It was possible to see interferograms changing with time.

In this variant the apparatus was combined with a television camera having an output to a vidicon unit and for videorecording, as well as a camera. Thus, it was possible to observe the initial state not only of the picture of change of the process through the hologram, but also all the phases of the process of the videomonitoring unit directly on the station or on the earth. Such a variant of the apparatus enables specialists, tracking the station from the earth, jointly with the cosmonauts, to participate in the control of holographic processes. In case of necessity the process after it ends can again be analyzed, consulting videorecords or a series of photographs which were taken.

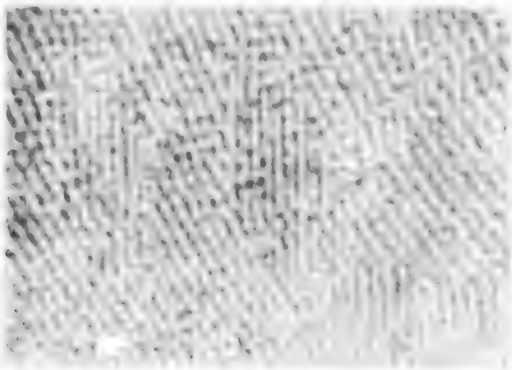
Preparation of Experiments

Space conditions will probably still for a long time superpose restrictions not only on the mass and volume of the instrument and the power which it requires, but also the time which can be expended on the experiment, especially if it transpires under the constant observation of cosmonauts. These conditions do not make it possible to vary the experiment to such a wide degree on the basis of intermediate data as is possible in the laboratory. Accordingly, the preparation for the space experiment is supplemented by preliminary laboratory experiments and experiments modeled on a computer (when this is necessary). In addition, since the "suppliers" of the experiment, as a rule, themselves do not execute it in space, there must be special training of the cosmonaut-operators, who although they are familiar with the working conditions in space, are not prepared for carrying out this experiment.

The implementation of a new space experiment is necessarily preceded by a test experiment. It should determine whether the proposed experiment will transpire under space conditions precisely as visualized and whether it will give a general picture of its peculiarities. It is not impossible that new scientific data will be obtained in the test experiment. Insofar as possible, on the earth it is necessary to simulate the conditions under which gravity, the key differentiating terrestrial conditions from space conditions, will be reduced to a minimum. It is necessary, to be sure, to take into account other secondary deviations from terrestrial conditions, such as temperature regimes. It

this is admissible, it is also possible to carry out a model numerical experiment on an electronic computer.

All these peculiarities in the preparation of space experiments fully apply to holographic experiments.



Microphotography of part of hologram.

Experiments on "Salyut-6" and "Salyut-7" Stations

In holographic experiments on the "Salyut-6" a study was made of the possibilities of transmitting holographic information from the station to the Flight Control Center and from the Control Center again to the "Salyut-6" station. The station received enlarged images of holograms which were then projected onto the photosensitive layer of the on-board television camera vidicon. The videosignal of the image of holograms was fed to surface stations and formed images on the videocontrol apparatuses, from one of which the images of the holograms were photographed. After the development of these images the holograms were used in restitution of the images of objects, which were then compared with the images retrieved from the initial holograms.

The transmission of holographic information in the opposite direction transpired as follows. The "Svet" holograph was used in forming holograms of the test-objects. They were projected onto the camera tube of a ground TV outfit and a videorecord of the holograms was obtained. During the television communication session this videorecord was transmitted to the station, where by means of special optical attachments and the videocontrol apparatus the transmitted holograms were photographed. The control photographs of these same holograms were also obtained on the earth. After appropriate processing there was retrieval of the images both from holograms obtained on the "Salyut-6" station and from the control photographs of the holograms and the retrieved images were compared. Experiments on the "Salyut-6," confirming the possibility of transmission of holographic information from aboard the station to the earth and back, also made it possible to evaluate the nature of the losses of the holographic information transmitted through the television channels.

It was found that virtually without losses it is possible to transmit only relatively low-frequency information (for example, interferograms obtained

with the double exposure of holograms on one sector of the film). In order to avoid high-frequency losses during the transmission of holograms it is necessary either to reduce the rate of transmission or to increase the number of frame elements. It became clear that the high sensitivity of transmission of holograms to different defects in the television channel makes it possible to use such transmission as a speedy method for quantitative checking of the quality of transmission of the image by the earth-space television system. In the course of these experiments it was also possible to clarify the possibility of transmission of holographic information concerning different processes at the rate at which they transpire, that is, at a real time scale.

The main task in holographic experiments on the "Salyut-6" station was a determination of the possibility of holographic work aboard an orbital space station and the checking of the performance of the KGA-1 apparatus developed for this purpose, an important detail of which was a gas laser. Before this a gas laser had not been used either in an instrument or separately on a station, that is, there had been no experience with work with it in space.

The program for experiments with the KGA-1 instrument, which were carried out by V. V. Kovalenok and V. P. Savinykh in March 1981, included holographic registry of different objects and processes. The objects selected were the following: a plane transparent object, from which it is possible to determine the quality of the holographic work; NaCl crystal, dissolving in water in a special cell; reflective three-dimensional object -- the internal parts of the holograph; and finally, transparent spatial relief, a glass plate simulating a station window with microdefects of the outer surface. The holographic photography of this surface should demonstrate how the KGA is to be used in checking the nature of damage on the station window during its prolonged use. In the holographic photography of the test-object use was made of an attachment without covering of the extra-axial reference beam, in the case of holographic photography of the window -- with coverage of the extra-axial beam.

The program for the holographic experiment also included an investigation to determine how small crystals of sodium chloride are dissolved under weightlessness conditions. We obtained holograms and interferograms (holograms with a double exposure) at different moments in time from onset of the dissolving process.

The results were interesting and to a certain degree unexpected: the process of dissolving of the sodium chloride crystals under weightlessness conditions was approximately 20 times longer than on the earth. During the first three hours the size of the crystal virtually does not change; then it decreases to a more conspicuous degree, but in the last stage its decrease is again slowed.

Holographic experiments were also continued on the "Salyut-7" station. On the one hand, plans called for the improvement of already tested holographic methods and apparatus, and on the other hand, broadening the range of their use. The KGA-2 apparatus with an attachment making it possible to obtain two-exposure holograms (interferograms) corresponding to different moments in the process was delivered to the station. The new apparatus was to be used as a recorder

of the isotachophoresis process for obtaining particularly pure biopreparations necessary in the production of highly effective medicines and solving problems in theoretical and practical microbiology. Among the methods for purification, separation and analysis of biopreparations an important place is occupied by electrophoresis in fluid solutions extremely effective in the separation of biopreparations at the level of proteins, subcellular particles and cells.

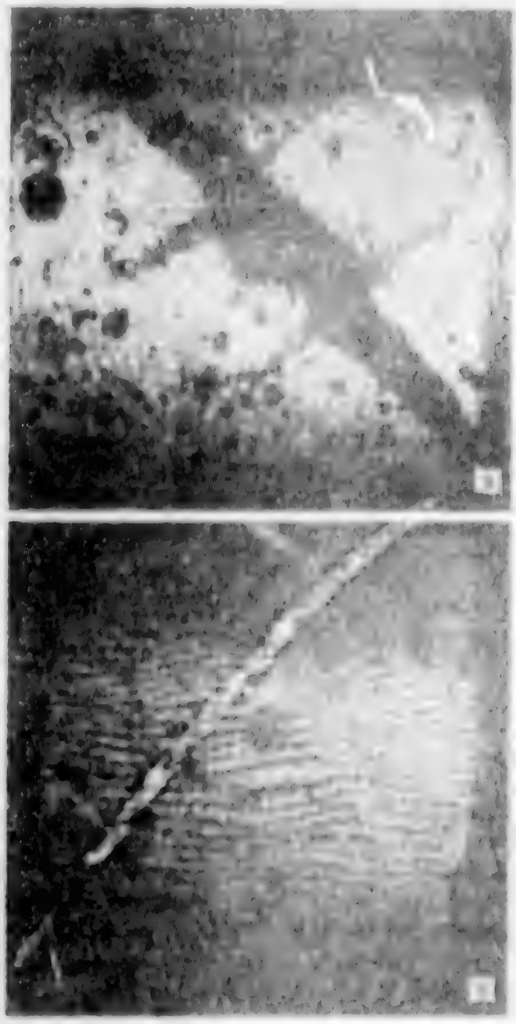
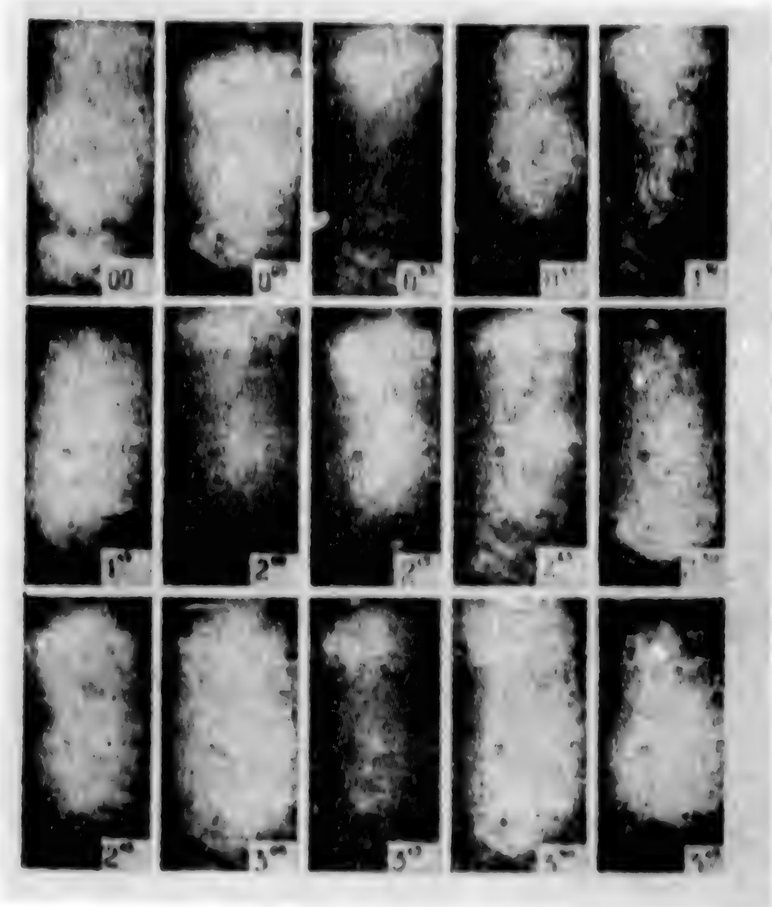
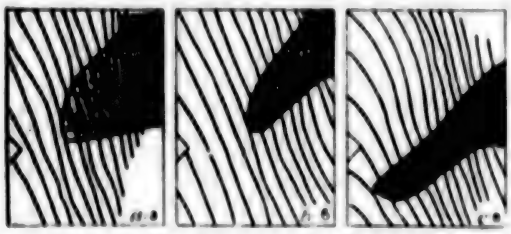


Image of sodium chloride crystal retrieved from hologram obtained on "Salyut-6" station (a). Interferogram of processes of dissolving of sodium chloride crystal retrieved from two-exposure hologram obtained on "Salyut-6" station (b).

A large series of laboratory experiments was carried out in preparation for the experiment. In this experiment it was possible to obtain interferograms of the electrophoresis process and isoelectric focusing of albumin. A series of interferograms gives the dynamics of displacement and separation of fractions in the electrophoretic column. The positioning of the fractions is determined from the curvature of bands of a finite width. In the experiment it was possible to make a quantitative evaluation of the change in the refractive



Images showing the change (in the course of three hours) in the appearance of an interferogram in an investigation of the dynamics of separation of fractions of biologically pure substances.



Graphic representation of isotachophoresis interferograms obtained on the "Salyut-7" station: a) from hologram obtained 46 minutes after onset of process; b) same after 52 minutes; c) same after 1 hour.

index of the pure fraction relative to the refractive index of a buffer solution. In addition, it was possible to determine the change in the gradient of the refractive index along the column on the basis of change in the slope of the interference bands. Laboratory experiments convincingly demonstrated that the KGA-2 apparatus registers the separation of biopreparations into fractions

and also makes it possible to observe and register the dynamics of the process of electrophoresis of unstained fractions, and accordingly, at a real time scale to monitor the segregation of superpure preparations.

A similar experiment on the "Salyut-7" station was carried out by the cosmonauts A. N. Berezovoy, V. V. Lebedev, L. I. Popov, A. A. Serebrov and S. Ye. Savitskaya. A hologram of the process which was then taken and later processed was used in retrieving the images of interferograms relating to different moments in the hourly course of the process. Forty minutes after the onset it is possible to observe local curvatures of the bands and a further change in their frequency and angle of inclination. These local changes determine the regions of appearance of biopreparation fractions.

The very same KGA-2 instrument was used in subsequent experiments during the second expedition on the "Salyut-7" station by the cosmonauts V. A. Lyakhov and A. P. Aleksandrov. Using the holographic apparatus, they studied heat and mass transfer in a fluid medium under weightlessness conditions. For this purpose they obtained a series of two-exposure holograms. The holograms will help in determining to what extent these processes in orbit differ from similar processes transpiring under terrestrial conditions.

V. A. Lyakhov and A. P. Aleksandrov also carried out experiments with an instrument and attachments intended for direct holographic and interferometric observation of processes of heat and mass transfer while they were transpiring.

Prospects for Holography in Space and on Earth

The successes of holographic experiments on the "Salyut-6" and "Salyut-7" stations make it possible to assert that other terrestrial possibilities of holography will find use in space.

There is much which can be done using holographic methods, such as for study of the peculiarities of behavior of fluids under weightlessness conditions. Capillary processes, wetting and hydrodynamic phenomena on the earth transpire in large part under the influence of terrestrial gravity. Under weightlessness conditions the behavior of a fluid is substantially impaired. Holographic apparatus makes it possible to register the form of the surface and the nature of movement of transparent fluids under weightlessness conditions. Holography will provide more than a few advantages in the investigation and registry of deformations, small displacements and vibrations.

It is of interest to use holography in microscopy. A series of holograms obtained in space gives a full picture of change in different microobjects. However, the direct use of a microscope in space is not always possible or effective and on the photographs taken with an ordinary camera it is impossible to see the photographed microobjects under a microscope due to the inadequate resolution of the optical system.

Up to this point we have told what holography gives to cosmonautics. But there is also a feedback. The holographic instruments and methods intended for space

may also prove to be useful on the earth. In actuality, the instruments existing earlier were suitable only for use in specially equipped laboratories. Space holographic apparatus will find its place even in the workshop, in colleges, in schools, since it is capable of giving surprising results which for the time being can be obtained only using massive laboratory apparatus. Finally, comparing the weight of the new holographic apparatus and an ordinary camera, we find that we are at the threshold of development of small-format mass holography. We can therefore be sure that the work expended on the development of instruments and methods for space will pay for itself not only in research in orbit, but also in the solution of different terrestrial problems.

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SPACE SCIENCES

'INTERSHOK' SPACECRAFT PLANNED FOR 1985 LAUNCH

Moscow IZVESTIYA in Russian 1 Jan 85 p 2

[Article by R. Sagdeyev, academician, director of the USSR Academy of Sciences' Institute of Space Research]

[Text] For me, the most pleasant moment of the year just past was connected with receiving the Lenin Prize for work on thermonuclear plasma physics in which I took part before I came to the Institute of Space Research. The fact that a scientist's works have proved to be of more than passing interest and have not become mere facts of his personal biography, but live, are beneficial and are used and advanced by his colleagues is unquestionably a source of satisfaction to him.

In 1984, the "Vega" spacecraft were launched to meet Halley's Comet, for the first time in human history. All of the terrestrial concerns connected with this program are now behind us; our voyagers are in free flight and their systems are functioning normally, as we say. But I am not about to state that this year was marked solely by the "Vega" mission. Work with one of the satellites of the "Prognoz" series was successfully completed, for example. This satellite gathered information in so-called relict radiation. Specialists believe that this radiation came into being at a very early stage in the origin of the universe. Events on Earth have been just as pleasing. I found out recently that my pupil Vladimir Zakharov has been elected a corresponding member of the USSR Academy of Sciences.

We have many plans for the new year, of course. We plan to launch a spacecraft in line with the scientific program "Intershok." We developed this program together with Czechoslovak scientists. Very sensitive and unconventional instruments will be installed on the spacecraft. They are to study physical processes in the cosmic shock wave produced by interaction between the Earth's magnetosphere and interplanetary plasma. And the busiest time of the year for us will begin in the summer: the "Vega" spacecraft will be approaching Venus, and their landing modules will begin studying this planet.

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UDC 528.48:621.396

ANGULAR ERROR OF POSITION OF RATAN-600 SCREENS DURING RADIAL DISPLACEMENT

Moscow GEODEZIYA I KARTOGRAFIYA in Russian No 8, Aug 84 pp 17-21

ZVEREV, Yu. K.

[Abstract] The accuracy of the main mirror of the RATAN-600 radiotelescope is determined primarily by the accuracy of manufacture of the surface of the reflecting elements and their placement in their calculated positions in radius, azimuth, elevation angle and altitude. Study of the azimuth and elevation angle errors arising upon radial displacement of the screen was a necessary element in combined studies of the radiotelescope performed in order to increase its effectiveness. The studies were performed using 23 screens from the central group of the north sector of the circular reflector. Measurements were performed by an autocollimation theodolite using 80 mm diameter mirror in 6 fixed positions on 2 different occasions. Each session included measurements with the screens moving forward and back. The major results of the study indicate that in spite of measurable errors in manufacture and installation of the rails of the supporting beam and carriage rollers, their influence on accuracy of the surface of the circular reflector of the radiotelescope can be reduced to the necessary level. Proper consideration of azimuthal errors is effective for wavelengths of over 4 mm. Tolerances determined are: rail bend 0.17 mm, nonplanarity 0.12 mm, ellipticity of horizontal rollers 0.12 mm, vertical rollers 0.08 mm, eccentricity of rollers 0.06 and 0.04 mm. Figures 3; references: 6 Russian. [9-6508]

UDC 523.982

ELEMENTARY SUNSPOT ENERGY MODEL

Moscow ASTRONOMICHESKIY ZHURNAL in Russian Vol 61, No 4, Jul-Aug 84 (manuscript received 17 Nov 82, after revision 21 Jun 83) pp 764-770

SOLOV'YEV, A. A., Kalmyk State University

[Abstract] An effort is made to explain the fact that the strength of the magnetic fields observed in spots varies in a quite narrow range (1000-4000 Oe). In addition, since a sunspot is a quite isolated and stationary

formation, an effort is made to ascertain whether the spot as a whole has characteristic oscillations, and if so, what might be the period. The study is based on an analysis of the total energetics of the spot, but with emphasis on change in the gravitational energy of the plasma as a function of the depth of immersion of the spot into the photosphere. These problems are examined using a simple model of a sunspot in the form of a vertical magnetic cylinder plunged into the photosphere. Calculations reveal that the main contribution to spot energy is from change in the magnetic and gravitational energy of the system. The model made it possible to find the stable equilibrium state of a sunspot for a given magnetic flux. The equilibrium value of magnetic field strength in a spot was determined as a function of its depth (lower boundary) and some characteristics of the medium surrounding the spot. Finally, the effective depth of the spot was estimated. A sunspot must be regarded as a relatively small formation because an acceptable numerical estimate for H_0 is found to correspond to a shallow depth of the lower boundary of the spot (1,000-1,500 km). The period of the small free oscillations of the spot is $T \doteq 5^m$. Figures 4; references 12: 8 Russian, 4 Western.
[192-5303]

UDC 523.98-337

MODELING 22-YEAR SOLAR ACTIVITY CYCLE WITHIN FRAMEWORK OF DYNAMO THEORY WITH ALLOWANCE FOR PRIMARY FIELD

Moscow ASTRONOMICHESKIY ZHURNAL in Russian Vol 61, No 4, Jul-Aug 84 (manuscript received 23 May 83) pp 783-788

PUDOVKIN, M. I. and BENEVOLENSKAYA, Ye. Ye., Leningrad State University

[Abstract] The R. B. Leighton model (ASTROPHYS. J., 156, 1, 1969) was used in a description of evolution of the magnetic field on the sun in the convective zone and at its surface. It was found that the maximum intensity which the background magnetic fields attain 2 years prior to the cycle maximum is 2.6-2.7 gauss in an epoch of an even cycle and 3.6-3.7 gauss in an epoch of an odd cycle at latitudes of about 10-20°N, S (4 gauss according to data computed from synoptic charts). The intensity of the polar fields averages 0.5 gauss, as is actually observed. A change in polarity of the polar fields occurs during the period of the solar activity maximum. Polar fields are formed by magnetic fields drifting from the middle latitudes. The middle-latitude fields have the polarity of the leading spots in the particular cycle and in each of the hemispheres. During the dropoff of the cycle the middle-latitude and equatorial fields have opposite polarity relative to the high-latitude fields. In the period of the minimum the magnetic fields in each of the hemispheres have an identical polarity. In the phase of growth of an odd cycle the middle- and high-latitude fields reverse their polarity. These and other findings reveal that the Leighton model gives a quite realistic distribution of background magnetic fields during two successive 11-year cycles and properly represents the general

behavior of the sun's surface magnetic field. The model is consistent with actual observations of the longitudinal component of the sun's magnetic field. Figures 2; references 9: 4 Russian, 5 Western.
[122-5303]

UDC 525.35/.37

SPECTRAL ANALYSIS OF DIURNAL NONUNIFORMITY OF EARTH'S ROTATION

Moscow ASTRONOMICHESKIY ZHURNAL in Russian Vol 61, No 4, Jul-Aug 84 (manuscript received 23 May 83) pp 806-811

PIL'NIK, G. P., State Astronomical Institute imeni P. K. Shternberg

[Abstract] Virtually nothing is known concerning the nonuniformity of the earth's rotation in the course of a 24-hour period. Astronomical time determinations for the period 1968-1978 revealed the existence of waves having a period of 24 hours or less which have definitely been identified with nonuniformity of diurnal rotation. According to the law of conservation of moment of momentum $C\omega$ = const. However, if pairs of forces are formed due to a nonuniform distribution of densities in the earth's interior and the instantaneous angular velocity ω changes, there should be a corresponding change in the moment of inertia. A thorough theoretical study of the possibility of such trembling is required. The diurnal rotation of the earth is much more complex than suggested by modern celestial mechanics. Formulation of a more precise model requires reliable determinations of the amplitudes and phases of all harmonics of the intradiurnal nonuniformity of the earth's rotation. It is recommended that such research be carried out within the framework of the international MERIT program. There is a need for accumulation of longer series of observations, but these must be broken down into parts and analyzed separately. Figures 2; tables 2; references 11: 6 Russian, 5 Western.
[192-5303]

UDC 523.64-1/-8

MAGNETIC FIELD PENETRATION INTO COMETARY IONOSPHERE

Moscow ASTRONOMICHESKIY ZHURNAL in Russian Vol 61, No 4, Jul-Aug 84 (manuscript received 12 May 83) pp 812-814

IOFFE, Z. M., Astrophysics Institute, Tajik Academy of Sciences

[Abstract] The possibility of penetration of a magnetic field into a cometary ionosphere is discussed in two recent studies (L. S. Marochnik, MOON AND PLANETS, 26, 353, 1982; A. I. Ershkovich, et al., JGR, 269, 743, 1983). The author critically examines the content of this research, pointing out

inconsistencies and ambiguities. Nothing has yet been published clearly demonstrating the possibility of the postulated magnetic field penetration. Theoretical considerations and experimental data summarized in this article enabled the autho. to visualize the following possible mechanism. The Kelvin-Helmholtz instability developing at the boundary of the ionosphere should lead to a breakdown of the continuous magnetic barrier into individual plaits having some degree of twisting. The field strength in the plait can increase to levels at which $B^2/8\pi \gtrsim W_{kin}$, where W_{kin} is the density of the kinetic energy of the undisturbed solar wind. The magnetic plait, a region of an intensified field, whose ends remain frozen into the solar wind, will be drawn into the coma plasma under the influence of magnetic attraction. Charged particles are reflected from the region of the stronger field, experiencing a sort of collision with it. The rate of penetration can be calculated by regarding a plait element as a heavy molecule. Estimates are given for all the pertinent parameters, from which it is found that the velocity of field motion can attain 10^5 cm·sec^{-1}. References 10: 6 Russian, 4 Western.
[192-5303]

UDC 550.388.8

OBSERVATION OF POLAR AURORA FROM THE SALYUT-6 SPACE STATION DURING THE GREAT GEOMAGNETIC STORM OF 11-13 APRIL 1981

Moscow GEOMAGNETIZM I AERONOMIYA in Russian Vol 24, No 4, Jul-Aug 84 (manusc t received 5 Oct 83) pp 620-624

LAZA , A. I., KOVALENOK, V. V. and YEVLASHIN, L. S., Polar Geophysics Institute, Kola Branch, USSR Academy of Sciences

[Abstract] An analysis is presented of the results of visual observation of auroras in the southern hemisphere performed by the cosmonauts of the 5th major expedition onboard the Salyut-6 space station, flying at about 350 km altitude. Notes made by the cosmonauts are quoted verbatim. The observations of 11 and 12 April 1981 were used to construct schematic maps showing the area of the auroras above the southern hemisphere. The observations allow clear determination of the geographic area and date and time of the aurora associated with the magnetic storm. Figures 2; references 14: 8 Russian, 6 Western.
[12-6508]

UDC 523.165

PULSATIONS OF COSMIC RAY INTENSITIES BEFORE INCREASING FLUX OF RELATIVISTIC PARTICLES FROM SOLAR FLARES

Moscow GEOMAGNETIZM I AERONOMIYA in Russian Vol 24, No 4, Jul-Aug 84 (manuscript received 10 Nov 83) pp 682-683

STARODUBTSEV, S. A. and FILIPPOV, A. T., Institute of Cosmophysical Studies and Aeronomy, Yakutsk Affiliate, Siberian Branch, USSR Academy of Sciences

[Abstract] A previous work showed that 24 hours before an increase in the flux of relativistic particles from solar flares, pulsations are observed in cosmic rays with periods of 30 to 40, 60 to 90 and less frequently 120 to 160 minutes. This work continues analysis of cosmic ray data several hours before the increase in flux of relativistic particles on the earth generated during solar flares. Five minute data from stations of the world network were analyzed for the events of 12 Nov 1960, 28 Jan 1967, 24 Jan 1971, 1 Sep 1971, 7 Aug 1972, 22 Sep 1977, 7 May 1978 and 23 Jul 1978. The results show that pulsations before solar flares cannot be caused by the influence of the atmosphere or magnetosphere on the intensity of cosmic rays. This indicates that the pulsations in cosmic rays before solar flares are of interplanetary or solar origin. References 2: 1 Russian, 1 Western.
[12-6508]

UDC 537.591

CYCLIC CHANGES IN BAROMETRIC COEFFICIENT OF COSMIC RAY NEUTRON COMPONENT

Kiev GEOFIZICHESKIY ZHURNAL in Russian Vol 6, No 5, Sep-Oct 84 (manuscript received 6 May 83) pp 73-75

ROGAVA, O. G. and SHATASHVILI, L. Kh., Geophysical Institute, Georgian Academy of Sciences, Tbilisi

[Abstract] The availability of new, more precise instrumentation and the accumulation of longer series of observational data have made possible a reassessment of the nature of change in 11-year variations in the barometric coefficient of the cosmic ray neutron component and a more precise allowance for the corresponding corrections for the barometric effect in continuous cosmic ray data. The authors computed series of barometric coefficients for Sanae station in Antarctica and Churchill station in Canada for the period 1957-1972. Convincing evidence was obtained of the existence of an 11-year cycle in changes of the barometric coefficient. The amplitude of the relative change $\beta/\beta\%$ of the 11-year cyclicity of the barometric coefficient β was about 7-8%, corresponding to the 11-year solar activity cycle. There is some tendency to a 2-year cycle of variations of the barometric coefficient which for $\beta^N-\beta^S$ is not manifested synchronously: when the oscillation attenuates at Sanae it appears at Churchill. A study made of the record for

Sanae station, made separately for even and odd years, suggests the presence of both annual and 2-year changes in the barometric coefficients and also variations with a period close to the period of 3-4 solar rotations, although the existence of the latter is determined less reliably. Figures 3; references 9: 7 Russian, 2 Western.
[19-5303]

UDC 521.1

SOME NUMERICAL ESTIMATES OF PERTURBATION OF ORBITAL ELEMENTS OF ARTIFICIAL EARTH SATELLITE WITH TOTAL DYNAMIC SYMMETRY ABOUT ROTATING ASPHERICAL EARTH

Dushanbe DOKLADY AKADEMII NAUK TADZHIKSKOY SSR in Russian Vol 27, No 6, Jun 84 (manuscript received 30 Nov 83) pp 314-317

KOYENOV, D. Z., Tajik State University imeni V. I. Lenin

[Abstract] The problem of motion of a satellite with total dynamic symmetry about a rotating aspherical earth was solved in an earlier study by the author (DOKL. AN TadzhSSR, Vol 26, No 6, 1983). With an accuracy to 10^{-8} it was possible to derive analytical formulas for perturbed Delaunay elements of a satellite orbit (for the parameters δL, δG, δH, δl, δg, δh and also for the perturbations of elements determining the earth's rotational motion). It was demonstrated that the Delaunay elements characterizing the translational motion of a satellite about the earth receive sensitive perturbations caused by the earth's figure. The elements determining the earth's rotational motion remain virtually constant. The formulas derived in the earlier study are now used to find the numerical values of the perturbation of Delaunay elements for a specific artificial earth satellite for a significant time period. The following case is examined: an artificial satellite of spherical configuration with perigee altitude 500 km, apogee altitude 1,000 km, longitude of ascending $\Omega = 45°$, angular distance of perigee from node $\omega = 30°$, orbital inclination $i = 57°$, moment of transit through perigee $\tau = 0$. The numerical values of the parameters entering into the right-hand sides of the formulas determining perturbations of the Delaunay elements are found. Employing the formulas derived earlier and the numerical values of all the constants, the perturbations of the Delaunay canonical elements are found for each day for 30 days, a time during which the satellite makes more than 350 revolutions about the earth. The numerical values of perturbations of Delaunay elements with an interval of 3 days are given in a table. Tables 1; references: 3 Russian.
[30-5303]

UDC 523.8.08

X-RAY EXPERIMENT ON 'PROGNOZ-9' ARTIFICIAL EARTH SATELLITE

Moscow VESTNIK MOSKOVSKOGO UNIVERSITETA, SERIYA 3: FIZIKA, ASTRONOMIYA in Russian Vol 25, No 5, Sep-Oct 84 (manuscript received 27 Dec 83) pp 81-88

KUDRYAVTSEV, M. I. and SVERTILOV, S. I., Nuclear Physics Scientific Research Institute

[Abstract] Instrumentation carried aboard the "Prognoz-9" artificial earth satellite made possible the simultaneous registry of X-radiation and charged particles of different types in a wide energy range. This provided data on background increases in the fluxes of X-radiation caused by increases in fluxes of charged particles and when necessary made it possible to exclude simulation of X-radiation events by charged particles. The satellite carried an RKh-1 scintillation spectrometer for measuring X-radiation fluxes in the ranges 10-50, 25-50, 50-100 and 100-200 keV. Two main operating regimes were employed: continuous and once per second. The RKh-1 consists of two identical sensors and an electronic circuit, with the angle between their axes being 15°. During the initial stage of the flight (July-August) the RKh-1 was oriented on the region of the galactic anticenter. Its field of view intercepted several X-ray sources, including the source in Crab nebula. In September-October the field of view did not intercept the galactic plane. The region of the galactic center, where the majority of bright X-ray sources was concentrated, began to enter the field of view in early November. A schematic diagram accompanying the text is used as a basis for a detailed description of RKh-1 operation. The principal sensing element of each sensor is a CsI(Tl) crystal with a thickness of 2.5 mm and a diameter of 80 mm. During the first half of the flight year the RKh-1 registered several hundred bursts of solar X-radiation. Good results were also obtained in studying cosmic gamma bursts of nonsolar origin and X-ray pulsars. Data are still being processed. The response of the RKh-1 in registering X-ray bursts was evaluated. The background counting rates in the energy ranges 25-50 and 50-100 keV were 22 and 19 pulses/sec. Assuming that a typical X-ray burst has a duration of 10 sec and a spectrum of the "optically thin plasma" type with kT = 50 keV, the energy release of the weakest bursts which could be registered is $\sim 2.5 \cdot 10^{-7} \mathrm{erg \cdot cm^{-2}}$. The RKh-1 field of view is such that the maximum time that a single source is observable is about 100 days. Assuming that a typical X-ray source has a power-law spectrum with an exponent ~ 3, the weakest fluxes from such sources which can still be registered at an energy of 25 keV is $\sim 3 \cdot 10^{-5}$ quanta$\cdot$cm$^{-2}\cdot$sec$^{-1}\cdot$keV^{-1} or at an energy of 50 keV -- $\sim 3 \cdot 10^{-6}$ quanta$\cdot$cm$^{-2}\cdot$sec$^{-1}\cdot$keV^{-1}. Figures 4; references 6: 4 Russian, 2 Western.
[27-5303]

UDC 528.225 629.783

USE OF ATMOSPHERIC MODELS IN PREDICTING ARTIFICIAL EARTH SATELLITE MOTION

Moscow IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY: GEODEZIYA I AEROFOTOS"YEMKA in Russian No 3, May-Jun 84 (manuscript received 5 Apr 82) pp 44-49

MALKIN, O. A., professor, doctor of physical and mathematical sciences, Moscow Order of Lenin Institute of Geodetic, Aerial Mapping and Cartographic Engineers

[Abstract] The atmospheric models, both static and dynamic, used in predicting motion of artificial earth satellites (AES) described in the Soviet and American literature are critically examined. Emphasis is on dynamic models based on direct observations. These models can be used in determining parameters at a given point in circumterrestrial space. They are used in relatively precise theoretical determination of AES position and predicting the behavior of a satellite at given times or in given time intervals. It is possible to determine the future time at which a satellite will arrive at a specific point in space. This requires that the proper atmospheric model (of which there are many) be selected. The author suggests an approach for comparing atmospheric models. A critique of work already done along these lines is presented. The comparison of models given in the article has a formal character because there is no objective criterion for the reliability of any of the models. However, the MSIS (D. Alcayde, et al., JGR, 83, A3, 1141, 1978) and FP (G. Thuillier, et al., J. ATMOS. TERR. PHYS., 39, 399, 1977) models are based on direct measurements and computations using these models should give a high degree of accuracy. Figures 2; 10 references: 2 Russian, 8 Western.
[163-5303]

UDC 528.2:629.78

USING VELOCITY VECTOR IN DETERMINING KEPLERIAN ORBIT OF GEODETIC SATELLITE

Moscow IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY: GEODEZIYA I AEROFOTOS"YEMKA in Russian No 2, Mar-Apr 84 (manuscript received 23 Nov 82) pp 49-55

ON'KOV, I. V., candidate of technical sciences, Perm Polytechnic Institute

[Abstract] The problem of determining the Keplerian orbit of a satellite on the basis of the known values of its velocity vector at three moments in time is examined and two methods for its solution are examined. Solution of this problem can be used in preliminary determination of the orbit of a planetary satellite on the basis of measurements of radial velocity and directions from three stations whose coordinates are unknown. The satellite velocity vector is found by solution of a system of three linear equations. After formulating the problem a geometrical solution is obtained. A solution with the use of derivatives requiring solution of a system of four nonlinear

equations with four unknowns is also presented. A series of expressions is derived which give a solution of the problem of determining satellite orbit from the velocity vector stipulated at three moments in time. The simple algorithms described can be used in the preliminary determination of the orbits of artificial earth satellites of the earth and planets. In the algorithm for obtaining a geometrical solution, in the case of excess observations, it is necessary to solve the key system of equations by the least squares method. Excess observations also make it possible to increase the accuracy in computing the derivatives of the velocity vector without changing the structure of the second algorithm. The proposed algorithms were checked in model artificial earth satellite orbits with different positions of the "observation" points in orbit. The results of these numerical experiments indicated the correctness of the proposed methods and the suitability of the algorithms for solving practical problems. Figures 2; references: 2 Russian.
[163-5303]

UDC 528.2:629.78:523.8

INVESTIGATING STATISTICAL CHARACTERISTICS OF ATMOSPHERIC BACKGROUND BRIGHTNESS AND STAR BACKGROUND DENSITY IN EQUATORIAL REGION OF CELESTIAL SPHERE

Moscow IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY: GEODEZIYA I AEROFOTOS"YEMKA in Russian No 2, Mar-Apr 84 (manuscript received 22 Oct 82) pp 56-60

VERESHCHAGIN, S. I., candidate of technical sciences, and LIKHOMANOV, S. A., graduate student, Moscow Order of Lenin Institute of Geodetic, Aerial Mapping and Cartographic Engineers

[Abstract] The statistical characteristics of atmospheric background brightness and star background density were determined in the equatorial region of the celestial sphere. Such data can be used in stipulating requirements on planned artificial satellites and in programming observations of faint astronomical objects. The basis of the statistical research method is modeling of m_{back} (atmospheric background brightness) or N (total number of stars) in each j-th circle of declination of the surveyed region and determination of the parameter K (the number of points in the entire region at which the brightness of the atmospheric background or star background density assumes the i-th value from a series of stipulated values). It was found that the dynamics of changes in brightness $\overline{m}_{back}$ as a function of lunar phase has a virtually identical character during all seasons of the year with a variation $\Delta m_{back} \leqslant 0^m.7$. This makes it possible to evaluate the need for using special methods and instrumentation for ensuring the required penetrability. A graph was constructed which can be used in estimating the mean annual efficiency in use of astrometric instruments and in selecting the dates when astronomical objects can be observed with a stipulated brightness. It was found that during the year there are periods when the star background density is minimum and the probability of appearance of a limiting

number of stars does not exceed a stipulated level. Knowing these periods it is possible to refine the evaluation of mean annual efficiency of astrometric systems based only on allowance for the lunar background. Figures 2; tables 2; references: 5 Russian.
[163-5303]

UDC 523.6

SYSTEMATIC AND RANDOM DEFORMATIONS OF ORBITS OF LONG-PERIOD COMETS

Moscow PIS'MA V ASTRONOMICHESKIY ZHURNAL in Russian Vol 10, No 5, May 84 (manuscript received 6 Jul 83, after revision 8 Dec 83) pp 394-396

ANTONOV, V. A. and TODRIYA, Z. P., Astronomical Observatory, Leningrad State University; Abastumani Astrophysical Observatory, Georgian Academy of Sciences

[Abstract] Cometary orbits can be classified on the basis of their semi-major axis a, each of which is characterized by a certain relationship between the solar gravitational force (SGF) and galactic perturbational forces (GPF). This article is limited to comets with a $\sim 10^3$-10^4 AU. In such cases the role of GPF gradually increases and they must be taken into account as small perturbations. These GPF are of a dual nature. They include regular forces (RF), systematically operative, and irregular forces (IF) of a random nature. For investigating this phenomenon the authors derived a system of differential equations for evolution of the orbital elements of a comet under the influence of the RF of the Galaxy on the assumption of a solar circular orbit. The study was limited to a Hooke perturbing potential approximation. The equations were averaged for the period of revolution of the comet around the sun. It was found that during half a galactic year the orbital elements change little as a result of perturbations. A system of averaged differential equations was derived for which a general solution was found. Particular attention was given to the case when the initial orbit is almost linear. In examining the IF it was necessary to make a series of simplifying assumptions. Formulas were derived which make it possible to compute changes in the Δp parameter for highly elongated orbits for different time intervals Δt for different a for both RF and IF. Computations revealed that with relatively small a and Δt the contribution of IF to the change in p is several orders of magnitude greater than the contribution of RF. But with an increase in a and Δt both types of perturbations become comparable in order of magnitude. The role of RF in the evolution of cometary orbits can be very significant, a fact which until now has not been fully recognized. References: 2 Western.
[164-5303]

UDC 521.1

ONE METHOD FOR CONSTRUCTING MODEL OF POINT MASSES OF PLANETARY GRAVITY FIELD

Moscow PIS'MA V ASTRONOMICHESKIY ZHURNAL in Russian Vol 10, No 7, Jul 84 (manuscript received 10 Oct 83) pp 549-553

TSERKLEVICH, A. L. and VOLZHANIN, S. D., L'vov Polytechnic Institute

[Abstract] Use of a multipoint form of representation of gravity potential has significant advantages in numerical integration of the differential equations of motion of a space vehicle near a planet. However, the traditional approach for determining the parameters of a model of point masses (MPM) is ineffective in constructing detailed and precise multipoint potential models. Accordingly, the authors propose a model based on determination of the anomalous masses of spherical pyramids obtained by dividing the body of a planet and their replacement by point masses situated at different depths at the centers of the bases of the pyramids. The method makes it possible to determine the parameters of a sufficiently large number of point masses and obtain a solution close to the optimum with the required accuracy. The proposed method was tested by constructing a model of 288 point masses uniformly approximating the earth's gravity field. The initial information used was 18 harmonic coefficients in the GEM 10 B geopotential model (F. J. Lerch, et al., MAR. GEOD., Vol 5, p 145, 1981). The earth was broken down into pyramids using a uniform 15° geographic grid. The standard deviation of the level service constructed using this model is 1.3 m. A 2-page table gives the parameters of the model, designated MTM-288. Tables 1; references 3: 2 Russian, 1 Western.
[191-5303]

UDC 629

MINIMAX PROBLEM OF ESTIMATING TRAJECTORY PARAMETERS IN CONTINUOUS FORMULATION

Moscow KOSMICHESKIYE ISSLEDOVANIYA in Russian Vol 22, No 4, Jul-Aug 84 (manuscript received 25 Jan 84) pp 483-498

LIDOV, M. L.

[Abstract] Estimating the parameters of a nearly circular satellite orbit about a center of mass is a special case of the general problem of determining the parameters of any trajectory in a continuous formulation. This paper is a theoretical analysis of the optimal estimation of a parameter in a class of linear estimates, assuming that the measurement errors contain two components which are not cross-correlated, one of which is white noise while the other is a random process with a known dispersion and an unknown correlation function. The calculus of variations is used to solve this problem of determining an unbiased linear estimation algorithm based on the minimization of the maximum of the unknown correlation function of the

dispersion of the estimate deviation from the true value of the estimated parameter. The particular case of the unperturbed low eccencitricity orbit of a satellite in a gravitational field is analyzed in some detail to demonstrate the development of the solution when the relationships change between the parameters of the uncorrelated and correlated components of the measurement errors. The appendices treat the conditions that the correlation functions must satisfy and demonstrate the existence of time measurement intervals which do not improve the parameter estimate. The purely theoretical treatment adduces no numerical examples or experimental data. References: 8 Russian.
[2-8225]

UDC 629.195.1

RESONANT ROTATIONS OF SATELLITE IN POLAR ORBIT IN MAGNETIC AND GRAVITATIONAL FIELDS

Moscow KOSMICHESKIYE ISSLEDOVANIYA in Russian Vol 22, No 4, Jul-Aug 84 (manuscript received 25 May 83) pp 499-506

BELETSKIY, V. V. and SHLYAKHTIN, A. N.

[Abstract] A second order differential equation is written for the planar rotations of a satellite about a center of mass in an elliptical polar orbit subjected to both gravitational and magnetic forces with the true anomaly as the independent variable. It is assumed in the solution that the permanent magnetic moment is directed along the axis of the satellite corresponding to the moment of inertia, the axis forming an angle with the current radius vector. The earth's magnetic field is a dipole field with the dipole axis coinciding with the earth's axis of rotation. The main resonances of the orientation of the satellite in absolute space, the current radius vector of the orbit and the current magnetic line of force are analyzed to demonstrate the feasibility of strict and stable orientation of the satellite with respect to these three orientations. It is possible to completely compensate eccentric oscillations of the satellite by the magnetic field. The special case of a circular orbit is analyzed in considerable detail, showing the magnetic field ranges for which stable solutions exist. Figures 5; references: 20 Russian.
[2-8225]

UDC 521.2

MULTISTEP ORBITAL CORRECTION ALGORITHMS FOR AN EARTH SATELLITE USING LOW THRUST ENGINE

Moscow KOSMICHESKIYE ISSLEDOVANIYA in Russian Vol 22, No 4, Jul-Aug 84 (manuscript received 8 Sep 82) pp 507-519

VASIL'YEV, V. V. and SALMIN, V. V.

[Abstract] Low altitude earth satellites are subjected to aerodynamic forces that can vary considerably in a short time, making precise prediction of orbital parameters difficult. It is possible to correct low elliptical orbits so as to compensate for these forces using low thrust engines such as ion reaction motors. The unpredictability of atmospheric density nonetheless necessitates the use of ongoing measurements of actual orbital parameters and the utilization of this data in a computer flight control system. This paper develops control algorithms based on analytical and semianalytical models of the controlled motion, which allow the updating of the control parameters with each orbit. The proposed correction algorithms provided for the step-by-step compensation of the perturbing forces via direct measurements and the calculation of the controlling data from approximate equations. The technique is illustrated with a comparative analysis of the approximate and precise determination of control parameters for the case when the orbital period and perigee are corrected, for the cases of both high and low solar activity levels, for an orbit having an apogee of 350 km and a perigee of 160 km. Simulation data for two atmospheric density models with corrections for each of 2-16 orbital revolutions show that the correction algorithm is not satisfactory when high precision is required in low orbits, though for the higher orbit with a perigee of 220 km and an apogee of 350 km, the algorithm is both efficient and within allowable tolerances. Figures 2; tables 3; references: 8 Russian.
[2-8225]

UDC 521.15

CONSTRUCTION OF CONDITIONALLY PERIODIC SOLUTIONS OF PROBLEM OF RECIPROCATING MOTION OF AXIALLY SYMMETRIC SATELLITE OF TRIAXIAL PLANET

Moscow KOSMICHESKIYE ISSLEDOVANIYA in Russian Vol 22, No 4, Jul-Aug 84 (manuscript received 15 Sep 82) pp 531-536

ZLENKO, A. A.

[Abstract] Previous papers by the author [KOSMICHESKIYE ISSLEDOVANIYA, 1981, Vol 19, No 5] formulated and solved the problem of the reciprocating motion of an axially symmetric satellite in the gravitational field of a triaxial planet for the case of double resonance. This paper continues the analysis with the construction of conditionally periodic solutions in the neighborhood

of the previous steady-state solutions for the averaged system of equations. The derivative function of a canonical transform is derived and the conditionally periodic solutions are written for different systems of variables which describe the reciprocating motion. It is shown that the steady-state motion can be interpreted as the motion of a point on a six-dimensional torus. With conditional periodic motion, the torus appears to pulsate periodically relative to the steady-state torus at a specified frequency and amplitude while the trajectory of the point on it experiences oscillations of the same type about the steady-state trajectory. The purely theoretical analysis adduces no sample calculations or experimental data. References 5: 2 Russian, 3 Western.
[2-8225]

UDC 525.7

PERTURBATIONS OF KALMAN FILTERING PROCESS

Moscow KOSMICHESKIYE ISSLEDOVANIYA in Russian Vol 22, No 4, Jul-Aug 84
(manuscript received 4 Feb 83) pp 537-542

CHERNOV, A. A. and YASTREBOV, V. D.

[Abstract] Kalman filters are widely used in navigation systems and the like, though the specific application of these filters in such actual data processing systems encounters a number of difficulties related to the lack of precise knowledge of the statistical characteristics of all of the ambiguities in the measurements and in the dynamical model employed. The desire to simplify the dynamical model leads to perturbations in the transfer matrix of the system. The linear equations which comprise the basis of the filter algorithms are most frequently the result of linearizing the true nonlinear equations. The filtering process is also disrupted by errors caused by the finite word length of the computer and anomalous measurements. Since an optimal filter designed around a computed model practically always operates under conditions other than nominal, this paper studies the perturbations of the estimates of the state vector due to perturbations of the matrices defining the dynamical system model. Formulas are derived for these perturbations of the state vector generated by a discrete Kalman filtering algorithm. The source of the perturbations is disturbances of the covariation matrix for the instrument noise, the covariation matrix of the filtering errors, the measurement matrix as well as the transfer matrix of the system and perturbations of the state vector estimate in the preceding step. The state vector formulas derived here can be used to select an efficient set of measurements and optimize the functioning of instrumentation systems for aircraft. The purely theoretical treatment adduces no sample numerical calculations or experimental data. References 10: 9 Russian, 1 Western in Russian translation.
[2-8225]

UDC 550.385.41

FAST ION POLARIZATION JET IN SUBAURORAL F-LAYER AND ITS MANIFESTATION IN STRUCTURE OF HIGH LATITUDE IONOSPHERE

Moscow KOSMICHESKIYE ISSLEDOVANIYA in Russian Vol 22, No 4, Jul-Aug 84 (manuscript received 20 Jun 83) pp 557-564

FILIPPOV, V. M., SHESTAKOVA, L. V. and GAL'PERIN, Yu. I.

[Abstract] The convection pattern in the subauroral region during a substorm exhibits a narrow band of fast plasma drift in a westerly direction. This rapid drift, called a polarization jet, was detected for the first time by the Cosmos-184 satellite at an invariant latitude of about 60°. Subsequent independent measurements of other intense polarization jets by the S3-2, OGO-6 and AE-C satellites showed that this structure is actually localized close to the polar wall of the main trough under conditions of moderate activity, i.e., close to the projection of the plasmapause at ionospheric altitudes. HF ionospheric sounding data from the Chatanika subauroral station is also analyzed to ascertain two typical situations, distinguished by the background ionization level in the F-region at the moment a polarization jet appears: 1) With a sufficiently high background ionization level in the F-region ($N_{e\ max}$ of about $5\cdot10^5$ electron/cm^3), at the moment the jet appears in the ionosphere sounding pattern, a trace is registered at a lower critical frequency and at a greater range than the main trace; 2) at lower levels (N_e of about $5\cdot10^4$ electron/cm^3), a trace with higher critical frequencies and at greater ranges appears, as compared to the main trace from the background layer ($F2_s$). The changes in the ionospheric structure with the development of a polarization jet over the observation station for these two cases of high and low background ionization are depicted schematically, showing that jet evolution over 15 to 30 minutes leads to the rapid devastation of the ionization in the lower portion of the F-layer, which corresponds to an extremely fast formation (or increasing depth) of a trough in the existing background ionization. Calculations of HF propagation paths also demonstrate that subtroughs in the ionization due to the development of a polarization jet influence the operation of HF communications links. Such jet data can be useful in optimizing high latitude HF services. Figures 2; references 26: 11 Russian, 15 Western.
[2-8225]

UDC 550.388

ION KINETICS, SMALL NEUTRAL AND EXCITED COMPONENTS IN D-REGION WITH ELEVATED IONIZATION LEVEL. III. VARIATIONS IN SMALL NEUTRAL AND EXCITED COMPONENTS

Moscow KOSMICHESKIYE ISSLEDOVANIYA in Russian Vol 22, No 4, Jul-Aug 84 (manuscript received 30 Jun 83) pp 565-571

SMIRNOVA, N. V., KOZLOV, S. I., VLASKOV, V. A. and OVCHINNIKOV, N. A.

[Abstract] Variations in the ionic composition of the D-region when exposed to a powerful ionization source (ionization rate of 10^3 to 10^9 $cm^{-3} \cdot s^{-1}$) were discussed in the previous two papers of this series [KOSMICHESKIYE ISSLEDOVANIYA, 1982, Vol 20, No 6 and 1983, Vol 21, No 6]. This paper analyzes the behavior of the following oxygen, hydrogen and nitrogen components at these ionization rates: $O(^3P)$, $O(^1D)$, O_3, $O_2(^1\Delta g)$; H, OH, HO_2, H_2, H_2O, H_2O_2; $N(^4S)$, $N(^2D)$, NO, NO_2 and N_2O. As the ionization level increases in the D layer, the influence of the ionized and small neutral components on each other also increases. The distributions of the overwhelming majority of small neutral and excited components are considerably disrupted. Concentrations of oxygen components decrease during the day at 60 km when the ionization rate is less than about 10^7 $cm^{-3} \cdot s^{-1}$ and at 70 km when the rate is 10^6 $cm^{-3} \cdot s^{-1}$, and begin to rise as the rate increases. At 80 km under nighttime conditions, these concentrations increase (with the exception of O_3) with a rise in the ionization rate. The influence of the season on the behavior of the oxygen components is manifest when the rate is 10^7 $cm^{-3} \cdot s^{-1}$. Concentrations of odd hydrogen components increase at altitudes below 80 km. The H and OH formation per electron-ion pair is governed by the altitude, ionization rate and the season. The concentrations of H_2O practically do not change under the above conditions. The concentrations of atomic nitrogen and NO increase substantially with an elevated ionization level. The NO formation per electron-ion pair is not a constant, being a function of the time of day, ionization rate and altitude. Figures 4; tables 2; references 14: 3 Russian, 11 Western.
[2-8225]

UDC 581.521

EXPERIMENTAL CHECK OF ION TRANSPORT MECHANISMS IN EARTH'S RADIATION BELT WITH EXPOSURE TO NONSTEADY-STATE ELECTRIC FIELDS

Moscow KOSMICHESKIYE ISSLEDOVANIYA in Russian Vol 22, No 4, Jul-Aug 84 (manuscript received 7 Feb 83) pp 572-587

PANASYUK, M. I.

[Abstract] It is assumed that the major mechanism for radiation belt formation with low or moderate magnetic activity is radial diffusion due to unsteady electric fields. Both magnetic and electric diffusion can be involved. This paper tests the conclusions of magnetic and electric diffusion theories by comparing theory and experiment for the position of the maxima of the radial profiles of the intensities of L_{jm} protons and heavy ions close to the geomagnetic equator. The analysis of the spatial distribution of these intensity maxima is based on H, He, C and O ions in an energy range of from 100 KeV to about 70 MeV. Calculations of these maxima for the energetic ionic component of the belts assuming magnetic or electric diffusion show that the spectra of the magnetic and electric field fluctuations in the center of the belt must differ substantially. The calculations are in good agreement with experimental data if the geomagnetic fluctuation spectrum is an f^{-2} function of frequency, while the electric field spectrum is flat. The measured spectra of the electric fields in this range of drift frequencies take the form of a monotonically declining function. The primary mechanism for the formation of ion radiation belts at energies above a few hundred KeV at shell levels L = 2 to 3.5 is the transport occurring with fluctuations in the geomagnetic field. In the outer drift shells of the radiation belt (L = 3.5 to 5), calculations of L_{jm}, given assumptions similar to those for the proton component but considering the loss of protons as a result of recharging, show that agreement is better with experiment when one takes into account the transport due to electric field fluctuations having a spectrum which varies as $f^{1 \text{ to } 2}$, and the upper estimate of the spectral density exceeds the corresponding internal radiation belt value. Similar calculations for the case of magnetic diffusion show good agreement between theory and experiment when the diffusion rate is the same for the outer belt regions and L = 2 to 3.5. The model which describes a considerable decrease in the magnetospheric electric field in the interior belt regions as compared to the auroral zone is best in light of the comparisons made here. Figures 5; tables 3; references 29: 5 Russian, 23 Western, 1 Western in Russian translation.
[2-8225]

UDC 533.95:551.510.535

ELECTRIC POTENTIAL OF SATELLITE IN ELECTRON EMITTING EXPERIMENTS IN INITIAL STAGE OF ELECTRON BEAM INJECTION IN STEADY-STATE MODE

Moscow KOSMICHESKIYE ISSLEDOVANIYA in Russian Vol 22, No 4, Jul-Aug 84 (manuscript received 16 Feb 83) pp 588-593

FEDOROV, V. A.

[Abstract] A theoretical study of the change in the electric potentials on a satellite in the initial stage of its injection of an electron beam into the ionosphere has shown that no blocking of the beam occurs and decaying plasma oscillations appear with the onset of electron injection. The steady-state mode starts at about the same time or before the neutral particle ionization time. No experimental data are available for the electric potential of a spacecraft or the plasma parameters in this initial injection time because the resolution of the instruments is about 10 msec, which is much greater than the onset time defined by theory for the steady-state. This paper derives a formula for the electric potential build-up on an electron emitting satellite as a function of the neutralization current, initial injection current, satellite radius and radius of the space charge region. The presence of ionospheric plasma ions in the space charge region is responsible for preserving a quasineutrality in the bulk of this region and the electric field potential declines slowly with distance. In the initial stage, satellite charge neutralization mechanisms, based either on the ionization of neutral particles of the plasma by accelerated electrons or on plasma heating by the injected beam, do not have time to act; satellite charge neutralization is accomplished only by ionospheric electrons. The determination of the satellite potential in the initial injection stage based on probe theory does not consider the presence of ionospheric plasma ions in the space charge regions and yields overstated results. Bringing the resolution of electric potential measurement instruments for these satellites down to about one microsecond will make it possible to observe the change in these parameters in the time interval before the neutral particle ionization time. This would permit an experimental confirmation of the presence of plasma oscillations occurring with the onset of beam injection and the establishment of the steady-state prior to this neutral particle ionization time. Tables 1; references 16: 10 Russian, 6 Western. [2-8225]

UDC 551.521.8

SPACE-TIME FEATURES OF SOLAR COSMIC RAY PENETRATION INTO HIGH LATITUDE REGIONS OF EARTH'S MAGNETOSPHERE BASED ON 'INTERCOSMOS-19' SATELLITE DATA

Moscow KOSMICHESKIYE ISSLEDOVANIYA in Russian Vol 22, No 4, Jul-Aug 84 (manuscript received 23 Feb 83) pp 594-598

GLUKHOV, G. A., KRATENKO, Yu. P., MINEYEV, Yu. V. and SPIR'KOVA, Ye. S.

[Abstract] The penetration of solar cosmic rays into the upper latitude magnetosphere increased during the strong magnetic storm of 3-5 April 1979 (the maximum D_{st} variation was -197 nT at 01 UT on 4 April). The data were obtained from the Intercosmos-19 satellite at an altitude of about 500 km in the northern hemisphere in the afternoon and evening MLT sector and in the southern hemisphere at about 1,000 km in the morning to night sector. Electron energies greater than 100 KeV and proton energies greater than 2.0 MeV were measured with gas discharge counters having a geometric factor of $4\cdot10^{-2}$ $cm^2\cdot sr$ and electrons at energies of 0.3 to 2.0 MeV and protons at 0.5 to 8.0 MeV were logged with a semiconductor telescope having a geometric factor of about 10^{-1} $cm^2\cdot sr$. Solar cosmic ray proton penetration is studied along with the evolution of the high latitude electron capture boundary for various electron energies. During the storm: 1) The position of the penetration boundaries shifted toward the equator; 2) there was a variety of fluctuations in the location of the boundaries of the different penetration regions; 3) rapid pulsations were observed for the penetrating particles on the day side of the magnetosphere close to the daytime polar cusp. The pulsation period of penetrating electrons of 15 to 20 sec correlates well with the fluctuations in the actual magnetic fluid. Possible mechanisms for the observed features are discussed though no firm conclusions are drawn. Figures 2; references 13: 5 Russian, 8 Western.
[2-8225]

UDC 550.383

MAGNETOHYDRODYNAMICS OF EARTH'S BOW SHOCK

Moscow KOSMICHESKIYE ISSLEDOVANIYA in Russian Vol 22, No 4, Jul-Aug 84 (manuscript received 4 Apr 82) pp 599-608

YESELEVICH, V. G.

[Abstract: Magnetohydrodynamics (MHD) equations have been applied before to the analysis of the earth's bow shock, with the distance of the shock wave from the center of the earth and the magnetopause thickness being determined experimentally. The values obtained for the latter were substituted in these analyses in Spreiter's formulas [PLANETARY AND SPACE SCIENCE, 1966, Vol 14] that have as the independent variable the adiabatic exponent. The values of the exponent range from 1.2 to 2. This paper is an analysis of

the accuracy of MHD calculations of the adiabatic exponent for the plasma behind the bow shock. MHD equations are solved for a plane shock wave discontinuity and the solutions are compared with experimental data from the Geos-1 and ISEE-1 and 2 satellites for 1969 and 1977. Functions are given which considerably improve the precision of the determination of the effective adiabatic exponent of the plasma behind the shock wave front. For a quasiperpendicular bow shock and Alfven Mach numbers of more than 2.5-3.0 (values of 5-6 are the most characteristic), plasma flow behind the front in the quasisteady-state is satisfactorily described by MHD equations with an adiabatic exponent of 5/3, while a value of 1.3 to 1.4 is satisfactory in the region of the "overshoot." Figures 5; tables 3; references 19: 3 Russian, 16 Western.
[2-8225]

UDC 551

SOME NEW PHOTOMETRIC DATA FROM PANORAMIC PICTURES TAKEN BY 'LUNOKHOD-2'

Moscow KOSMICHESKIYE ISSLEDOVANIYA in Russian Vol 22, No 4, Jul-Aug 84 (manuscript received 15 Mar 83) pp 609-616

BUSAREV, V. V., ZASETSKIY, V. V., KANTAROVSKIY, Yu. A., TITOV, V. I. and SHEVCHENKO, M. Yu.

[Abstract] Pictures taken during the third and fourth lunar operating days of the Lunokhod-2 unmanned lunar exploration vehicle were processed photometrically in order to detail the photometric properties of the moon surface material in its natural state. Photometric markers in the field of view of the remote panoramic photometers were used to find the comparative brightness of the lunar landscape features for the purpose of determining their albedo and the nature of light reflection under changing illumination and observation conditions. The markers were flat metal plates with 39 rectangular brightness fields on the front group in 3 columns, each field column having a set of different gradations of brightness from black to white. Two panoramic pictures were broken down into several sections in order to distinguish the photometric data from the undisturbed surface and that disturbed by the passage of the lunar vehicle. The theoretical and empirical distributions of the photometric function for four of these subsections are plotted graphically, showing that the form of the empirical function is governed primarily by the true photometric relief. Variations in the functions for the other sections are discussed and it is noted that the values found for the albedo (e.g., 7.01 $\pm$ 0.02 for section 1 of panorama 4-1, which is representative of the entire surface in that panorama) can be considered typical of all of the regions of the surface in these pictures, since the agreement between the average and particular photometric function was confirmed for the sections of homogeneous undisturbed surface. The actual panoramic photos are also shown. Figures 4; references 15: 10 Russian, 4 Western, 1 Western in Russian translation.
[2-8225]

UDC 517.11:531.382

APPLICATION OF QUATERNIONS TO PROBLEMS OF SOLID BODY DYNAMICS IN THE ATMOSPHERE

Moscow KOSMICHESKIYE ISSLEDOVANIYA in Russian Vol 22, No 4, Jul-Aug 84 (manuscript received 9 Mar 83) pp 626-629

LOKHOV, G. M. and PODZOROV, S. I.

[Abstract] A hard, free solid body moves in space; its position is specified by means of a matrix of direction cosines. Kinematic equations using trigonometric formulas are impractical because of the volume of computations involved. The theoretical advantage of Rodrigo-Hamilton parameters for platformless orientation and navigation in space has already been demonstrated; these permit a reduction in the computational requirements. Previous literature studying the dynamics of solids in the atmosphere using quaternions treated only an asymptotic solution of the problem of body orientation. This paper compares the computational requirements and convenience of direction cosines and Rodrigo-Hamilton parameters for the atmospheric case. It is assumed that the body is an ideal solid of rotation, its center of mass is on the longitudinal axis of symmetry and the major inertial axes are parallel to the lines of aerodynamic symmetry. A mathematical model is constructed which can also be applied to the flight dynamics of an asymmetric solid in the atmosphere. The resulting two sets of direction cosine and quaternion equations were used for the numerical solution of the same problem. Numerical integration was accomplished with an explicit fourth order Runge-Kutta method with a small initial step of $\Delta t = 0.001$. The solutions were in practically complete agreement, though the quaternions were twice as economical as the matrix notation, thus recommending them as the most convenient kinematic parameters not just for problems of orientation in space, but also for numerical simulation of solid dynamics in the atmosphere. The application of quaternion formulas to kinematics equations also facilitates the modeling significantly. References: 12 Russian.
[2-8225]

UDC 581.521

MODELING LONGITUDINAL MOTIONS OF THERMAL O^+ AND H^+ IONS IN MAGNETIC FIELD TUBE CONVECTIVE THROUGH DAYTIME POLAR CUSP

Moscow KOSMICHESKIYE ISSLEDOVANIYA in Russian Vol 22, No 4, Jul-Aug 84 (manuscript received 30 Mar 84) pp 629-631

ZININ, L. V.

[Abstract] The altitude profile of the concentrations and velocities of thermal ions in a magnetic field tube passing convectively through the daytime polar cusp to the cap undergoes a considerable dynamic restructuring. With the intersection of the cusp for a few minutes, the plasma experiences a short term heating and additional ionization by low energy electrons close to and below the F-layer maximum, after which the field tube relaxes. This paper employs a modified nonsteady-state polar wind model to analyze the longitudinal motions of ions in a field tube about 50,000 km long, both for O^+ and H^+ ions, and to estimate the flow of these ions into the magnetosphere. The results of calculating the fluxes $F(O^+)$ and $F(H^+)$ as well as the longitudinal velocities $V(O^+)$ and $V(H^+)$ are summarized in two tables for times of from 0 to 160 minutes after exiting the cusp for altitudes of 600, 1,000, 1,500, 2,050, 4,000, 7,920 and 23,050 km. A hydrodynamic mechanism for the entry of thermal O^+ ions from the polar ionosphere into the magnetosphere is described; it must play a considerable part in the observed filling of the magnetosphere with energetic O^+ ions. The $F(O^+)/F(H^+)$ ratio is calculated as about 0.1 for quiet conditions; the ratios for moderately disturbed conditions with convection through the cusp are in agreement with data from satellites such as the GEOS series. The author is grateful to Yu. I. Gal'perin for his attention to the work and discussion of the data as well as N. K. Osipov, K. S. Latyshev and S. A. Grigor'yev for advice and support in developing the model. Tables 2; references 11: 2 Russian, 9 Western.
[2-8225]

UDC 523.037:525.7

ELECTRON FLUX WITH ELECTRON ENERGIES ABOVE 40 MeV AT ALTITUDES OF ABOUT 500 KM IN REGION WHERE CAPTURE IS POSSIBLE AND OUTSIDE IT WHEN L IS 3 OR GREATER

Moscow KOSMICHESKIYE ISSLEDOVANIYA in Russian Vol 22, No 4, Jul-Aug 84 (manuscript received 25 Jul 83) pp 632-634

KURNOSOVA, L. V., RAZORENOV, L. A. and FRADKIN, M. I.

[Abstract] The electron flux for energies greater than 40 to 50 MeV at altitudes of 400 to 500 km in the capture region for a geometric shell parameter of $L \geq 3$, i.e., close to the outer belt boundary is compared with the electron flux outside the capture region when $L \geq 3$. Data from the Cosmos-225 (1968) were used. This data reduction was done because of the detection of electrons with energies above 40 MeV in the inner radiation belt and a report of an elevated electron flux in the outer belt. The analysis shows that electrons under these conditions have the same flux levels both inside and outside the possible capture regions. The maximum difference in the flux levels in these two regions cannot exceed about 80 $m^{-2} \cdot s^{-1} \cdot sr^{-1}$. Figures 1; references: 9 Russian.
[2-8225]

UDC 581.521

BOUNDARY OF MODULATION DIFFUSION AND STOCHASTIC INSTABILITY OF HIGH ENERGY PROTONS IN INNER RADIATION BELT

Moscow KOSMICHESKIYE ISSLEDOVANIYA in Russian Vol 22, No 4, Jul-Aug 84 (manuscript received 5 Apr 83) pp 634-637

AMIRKHANOV, I. V., GUSEV, A. A., IL'IN, V. D., IL'INA, A. N. and PUGACHEVA, G. I.

[Abstract] The motion of an individual charged particle in an axially asymmetric trap such as a geomagnetic trap is fundamentally unstable because of the so-called universal instability of a Hamiltonian systems with three or more degrees of freedom. This instability is also called Arnold diffusion instability. If there are regions of motion that are always stable in the two-dimensional case (an axially symmetric field), then instability during finite time intervals is a feature of the three-dimensional case. The duration of these intervals is governed by the Arnold diffusion rate, which depends greatly on the Larmor radius and the pitch angle of the particle and can reach cosmic scales. Modulation diffusion, which is related to the multiple structure of nonlinear resonances between the cyclotron rotation and higher harmonics of the longitudinal particle oscillations can occur in addition to the Arnold diffusion. The limiting case of these instabilities is stochastic instability involving the

overlapping of the stochastic layers of nonlinear resonances. The particle losses will be described by different diffusion coefficients, depending on the type of instability, and so it is of practical importance to know the boundaries of the regions of existence of these instabilities as precisely as possible. This paper determines the modulation diffusion and stochastic instability boundary of high energy particles for the actual geomagnetic field using a fourth order Runge-Kutta-Gills approximation and a RYaD-1040 computer for the case of 400 MeV protons. The available experimental data are in agreement with the calculated values, yielding an upper limit of the stochastic instability for pitch angles of less than about 30°. Figures 2; references 9: 7 Russian, 2 Western.
[2-8225]

UDC 612.014

SPACE RADIATION MONITOR OBSERVATIONS FROM 'SALYUT-4' ORBITAL STATION

Moscow KOSMICHESKIYE ISSLEDOVANIYA in Russian Vol 22, No 4, Jul-Aug 84 (manuscript received 9 Dec 82) pp 637-639

LYAGUSHIN, V. I., MAMONTOVA, N. A., MAKHMUDOV, B. M., SARAYEVA, M. A., SHAVRIN, P. I. and YUSHKOV, Yu. Yu.

[Abstract] Space radiation levels were monitored with the "Ryabina" equipment from the "Salyut-4" space station between December 1974 and July 1975; neutrons and charged particles were recorded with two energy thresholds for the detector. This paper is a summary of the reduced data from the 3,000 orbits. The charge particle count rates for the various energy levels are plotted as a function of time. It is noted that such observations, even with omnidirectional detectors, require consideration of both the trajectory and orientation of the satellite. The best observational conditions occurred during the deep solar activity minimum, which enabled an evaluation of the effect of orientation on the "Ryabina" detectors. All other factors (with the exception of the dependence on longitude and geomagnetic perturbations) do not play a very important part. The authors are grateful to N. D. Masanov and R. N. Basilov for their valuable assistance. Figures 2; references 5: 4 Russian, 1 Western.
[2-8225]

INTERPLANETARY SCIENCES

KOVTUNENKO COMMENTS ON 'VEGA' FLIGHT PLAN, INSTRUMENTATION

Tallinn SOVETSKAYA ESTONIYA in Russian 16 Dec 84 p 3

[Article by Yu. Zaytsev, department head, USSR Academy of Sciences' Institute of Space Research]

[Abstract] The author gives a brief background commentary on the planning of international space projects to study Halley's Comet, and he records a lengthy commentary by Prof V. M. Kovtunenko, corresponding member of the Ukrainian Academy of Sciences, regarding the "Vega" mission involving two Soviet "Venera" space stations. Kovtunenko is the director of the "Vega" mission. He related the following about the scheme of the "Vega" spacecraft's flight:

"Each of the three main objectives of the 'Vega' mission--investigation of Venus with the aid of a landing module and an aerostatic probe, and of Halley's Comit from a flyby trajectory--presents its own specific requirements to the ballistic scheme of flight.

"On the one hand, this scheme must ensure that the landing module (which does not have its own control systems) is guided into Venus' atmosphere with the prescribed entry conditions. For example, the aerostatic probe will enter on the dark side of the planet, at a point nearly opposite the sun. Finding itself in thermal equilibrium with the [atmosphere], it will begin to drift with the wind and move toward the daylight side of the planet. This will ensure maximum direct radio visibility of the probe with measurement posts on Earth, and maximum duration of its 'voyage' in the atmosphere of Venus.

"On the other hand, the station itself, in the process of the landing module's descent [following its release] and its operation on the surface, must move in a very precise manner in the zone of communications with the module, because the station will serve as a relay for the module's signals to Earth. In this circumstance the station is not able to move into a flight path that will take it toward Halley's Comet, and therefore an additional maneuver is necessary after it passes Venus."

Kovtunenko went on to discuss modifications made in the "Venera" stations to "toughen" them for flying through the comet's coma, and to describe the stations' instrumentation. He related:

"The station has an armor in the form of two-layer (and three-layer in certain spots) screens which protect its vital points, and also scientific apparatus and a network of cables.

"Even this protection, however, as was shown from using an engineering model of Halley's Comet, cannot serve as a reliable guarantee against damage from [possible] collisions with dust particles. Therefore it was necessary to dispense with the recording of scientific and operational information in a memory device and to plan for direct transmission of data to Earth. This in turn necessitated constant orientation of the narrow-directional antenna toward Earth during the station's flight near the comet's nucleus. Moreover, the flight of a spacecraft inside the coma will not allow orientation of the station in this sector with the aid of optical sensors, which led to the necessity of using a gyroscope system of stabilization. Part of the scientific instruments for studying the comet's nucleus by optical means had to be installed on a rotating stabilized platform which was specially developed for the flyby spacecraft.

"The development of this platform has no precedents in space scientific instrument building. It is a precise servomechanism with two degrees of freedom. Ten to 15 days before the moment of maximum approach to the comet's nucleus, the platform will be set into working position with the aid of an engagement mechanism, on command from Earth.

"Scientific apparatus is mounted on a frame which is fixed to the wheel of a servodrive. Mounted on the platform are instruments for spectrometric measurements in various regions (from infrared to ultraviolet), and a phototelevision system. The latter will make it possible to receive black-and-white and spectrozonal color pictures of the central region of the coma on various scales.

"In addition to the apparatus on the stabilized platform, there are a number of scientific instruments installed directly on board the 'Vega' stations. They are intended mainly for studying the chemical composition of the comet's matter and the properties of the gas and plasma surrounding it."

FTD/SNAP
CSO: 1866/67

COMMENTS ON 'VEGA' MISSION

Moscow IZVESTIYA in Russian 16 Dec 84 p 2

[Article by G. Alimov]

[Excerpt] An automatic interplanetary station for conducting a multipurpose program for the study of two heavenly bodies--the planet Venus and the famous Halley's Comet--in a single mission has now been launched from the Baykonur Cosmodrome.

Why is this spacecraft flying toward the mysterious wanderer, what tasks lie ahead of it?

"What motivates the scientists is not idle curiosity," said Academician Roal'd Zinnurovich Sagdeyev, scientific director of the "Venus-Halley" ("Vega") program. "Comets are most probably the remains of the cloud of gas and dust from which the Solar System was formed. In other words, they are a kind of prototypical cosmic building material. They may contain unique information about the physical and chemical processes which occurred at the moment of the birth of the Solar System. And the chemical transformations of molecules in conditions that are unique to a comet could have served as the primary cause of the appearance of organic matter in the Earth's atmosphere.

"Our scientists have prepared the project together with specialists from the countries of the socialist commonwealth, as well as from France, Austria and the Federal Republic of Germany."

"On the spacecraft," related Vyacheslav Mikhaylovich Kovtunenko, head of the project, "diverse scientific instruments are installed. Some were made by specialists of countries participating in the program, while others are Soviet-made instruments. For example, a television system has been installed on the station. We expect that it will provide black-and-white and spectral pictures of different scale of the comet. The spatial resolution of the long-focus camera will be 180 meters. Data from the TV system will also be used to guide the rotating platform which will aim the instruments at the comet. Mass spectrometers, a magnetometer and an electron analyzer will be in operation on the spacecraft. It also has its own radio-equipment complex on board--it will permit 'radioscopy' of the comet's plasma and radiolocation of its nucleus, head and tail. The interplanetary station will begin to transmit information about the heavenly visitor 1.5 to 2 hours before the encounter with it. The entire communications session will last about 3 hours before the voyager from Earth disappears forever in the depths of the universe."

FTD/SNAP
CSO: 1866/67

PRESS CONFERENCE ON FLIGHT OF 'VEGA' SPACECRAFT

Moscow TRUD in Russian 29 Dec 84 p 1

[Text] The automatic interplanetary stations "Vega-1" and "Vega-2," which were launched on 15 and 21 December, are successfully continuing their flight to Venus and Halley's Comet. This was reported to Soviet and foreign journalists at a press conference which took place in the press center of the USSR Ministry of Foreign Affairs on 28 December.

Speaking at the press conference, Academician R. Sagdeyev, chairman of the International Scientific-Technical Committee for the "Venus"--"Halley" Project, said that the development and launching of these spacecraft, which are designed for carrying out a complex program with many stages, represent a new achievement of Soviet science and technology, and give evidence of the high effectiveness of international cooperation in the peaceful exploration of space. He noted that 20 years of research experience within the framework of the "Intercosmos" program has made it possible this time to unite the efforts of the nine countries that are taking part in the realization of the project: Austria, Bulgaria, Hungary, the German Democratic Republic, Poland, the USSR, France, the Federal Republic of Germany, and Czechoslovakia. The scientist emphasized that the experiment's successful beginning confirms that the path of international cooperation is one on which researchers anticipate major new achievements.

V. Kovtunenko, corresponding member of the USSR Academy of Sciences and head of the project, and V. Barsukov, corresponding member of the USSR Academy of Sciences, also told about the contribution which scientists of various countries are making to carrying out this project of the century and about the experiment's significance and scientific goals. In particular, they informed those present that the first of five planned corrections of the automatic stations' flight paths was executed on 20 and 27 December. The space telecommunications center is constantly monitoring the course of the flight of both spacecraft, which will reach the vicinity of Venus in June of 1985 and pass close to Halley's Comet in March of 1986.

FTD/SNAP
CSO: 1866/67

RESULTS ON VOLCANISM, SURFACE GEOLOGY FROM 'VENERA-15, -16'

Moscow IZVESTIYA in Russian 15 Dec 84 p 3

[Article by B. Konovalov, science commentator]

[Excerpt] Soviet automatic stations have discovered hot spots on the surface of Venus, which, in the opinion of scientists, may prove to be active volcanoes.

For a year and a half, the Soviet automatic stations "Venera-15" and "Venera-16" have been conducting studies of the planet nearest to us, from orbits as Venus satellites. In December, a working session of Soviet scientists, at which a preliminary summation of this long-term work was made, took place at the "Medvezh'i Ozera" tracking station, where a huge 60-meter dish antenna is receiving radio signals from Venus.

"In addition to pictures of the surface of the previously unexplored polar region, we have obtained a thermal map of practically the entire northern hemisphere of Venus," said corresponding member of the USSR Academy of Sciences A. F. Bogomolov in opening the meeting. "It shows vast areas in which the temperatures recorded by the radiometer are below the average temperatures for Venus (about 500 degrees Celsius). These are lava-covered regions. What is most interesting, however, is the discovery of several hot spots with a temperature of about 700 degrees Celsius. It is entirely possible that they are active volcanoes."

"In the pictures transmitted by the 'Venera-15' and 'Venera-16' stations, we see many domed structures which resemble volcanoes," said A. T. Bazilevskiy, head of the laboratory of comparative planetology of the USSR Academy of Sciences' Institute of Geochemistry and Analytical Chemistry. "One must determine whether these are ancient volcanoes, of which there are many on Earth, or young ones. At our institute, we keep receiving more and more new pictures of the planet's surface in which we see geological formations resembling those on Earth--fold mountains, expansion zones similar to those at the bottom of our oceans, ancient ring structures. On Earth, all this is covered either by a mass of water or by a sheath of sedimentary rocks, while on Venus, as if in a geological nature preserve, everything can be studied without interference. Now we must match all the pictures with the thermal map of Venus. This will provide very valuable material for analysis."

Through the joint efforts of specialists of the experimental design bureau of the Moscow Power Engineering Institute and the USSR Academy of Sciences' Institute of Radio Engineering and Electronics, Institute of Information Transmission Problems, and Institute of Applied Mathematics, the data-processing process is steadily improving, and from session to session the quality of the pictures obtained gets better. Over 300 communications sessions have already been conducted and 120 million square kilometers of the planet's northern hemisphere have been mapped. Our heavenly neighbor's previously unknown polar region has now revealed itself to science on Earth. A vast plain was found to lie near the pole, crossed by ridges here and there. It is surrounded by mountainous areas, in particular, by the huge semicircle of the vast Ishtar Terra, where in the Maxwell Mountains there are peaks of about 12 kilometers--higher than our Mount Everest.

The study of the Venusian atmosphere has also brought surprises. This planet does not cease to surprise science on Earth. Therefore Soviet automatic stations are once again being sent to it in order to lift the next veil of mystery from our nearest and most enigmatic planetary neighbor.

FTD/SNAP
CSO: 1866/67

UDC 550.311+551.12+523.52

INTERPRETATION OF VENUS GRAVITATIONAL ANOMALIES

Moscow KOSMICHESKIYE ISSLEDOVANIYA in Russian Vol 22, No 4, Jul-Aug 84
(manuscript received 27 Jul 82) pp 617-621

TARAKANOV, Yu. A., KAMBAROV, N. Sh., PRIKHOD'KO, V. A. and BONDARENKO, D. R.

[Abstract] Doppler tracking of the Pioneer Venus satellite orbit provided accurate data on Venus' gravitational field in the form of harmonic coefficients of the gravitation potential expansion out to the sixth order, but because of the poor precision of the determination of the last three harmonics, only the second and third order coefficients have been published up to now. Three characteristics of the gravitational field are calculated from the anomaly gravitation potential expansion coefficients: the height of the Venus geoid and the gravitation force component at the meridian (the deviation of a plumb line in the plane of the meridian) as well as the attractive force component with respect to the planetary radius. The epicenters and amplitudes of these three characteristics are summarized in tabular form for the five largest anomalies on Venus: the central and northeastern areas of the Aphrodite region, the western area of this region, the Ishtar region and the southern region. The amplitudes of the geoid altitudes reach 40-60 m, the gravitational forces reach 20-30 mGal and the plumb line deviations reach 4" (20 mGal), which is generally in agreement with the earth's anomalies for the three harmonics. The considerable smoothing of the gravitation field substantially overstates the depth of these dense inhomogeneities. This new interpretation technique is sensitive to this smoothing; such smoothing of earth anomalies, with the approach of reducing the number of harmonics to 3, increases the true value of the height by a factor of 1.4. The corrected depths of the centers of the Venus anomalies then fall in a range of 700 to 800 km, corresponding to the depth of the second phase boundary. This may indicate that the physical factor underlying the planetary gravitational anomalies of both Venus and the earth is fluctuations in the position of this second phase boundary. Figures 1; tables 2; references 10: 9 Russian, 1 Western.
[2-8225]

UDC 523.46.47

STRUCTURE AND ORIGIN OF MARTIAN SATELLITES

Moscow ASTRONOMICHESKIY VESTNIK in Russian Vol 18, No 2, Apr-Jun 84 (manuscript received 17 Feb 84) pp 83-99

ZHARKOV, V. N., KOZENKO, A. V. and MAYEVA, S. V., Institute of Physics of the Earth imeni O. Yu. Shmidt

[Abstract] The most recent reviews of the structure and origin of the Martian satellites Phobos and Deimos were published by J. A. Burns and J. B. Pollack several years ago. In this article the authors update these reviews on the basis of the most recent observational data and theoretical studies. The following tables are given: 1. Parameters of Martian satellites and their orbits; 2. Characteristic accelerations; 3. Abundances of radioactive elements; 4. Thermal models for different thicknesses of regolith layer; 5. Thermal models of Phobos and Deimos. Different sections deal with structural characteristics, preliminary seismic models, figures and gravity fields, distributions of temperature and heat flow, orbital evolution and origin of the two satellites. A critical review of the published literature is presented. With respect to the origin of these bodies, the authors exhibit great interest in the idea that in the past Mars had a great number of small satellites. It is felt that the origin of Phobos and Deimos cannot be understood if this new idea is not taken into account. It may be that a swarm of small bodies was captured or a swarm formed at the time of collision and disintegration of asteroids in the neighborhood of Mars. Thus, the problem of the capture of Phobos and Deimos may be related to the problem of the capture of a great many small bodies. On the other hand, many of the captured satellites may have perished in the early stages of formation of Mars. Therefore, Phobos and Deimos may be the last of numerous once existing but now "forgotten" satellites of Mars. Figures 9; tables 5; references 30: 7 Russian, 23 Western.
[172-5303]

UDC 523.31

DISTRIBUTION OF GRAVITY AND PLUMB LINE DEFLECTION AT MARTIAN SURFACE

Moscow VESTNIK MOSKOVSKOGO UNIVERSITETA, SERIYA 3: FIZIKA, ASTRONOMIYA in Russian Vol 25, No 1, Jan-Feb 84 (manuscript received 17 May 83) pp 64-69

MAKSIMOVA, T. G. and CHUYKOVA, N. A., State Astronomical Institute imeni P. K. Shternberg

[Abstract] In the case of Mars it is impossible to use as the surface of relativity a sphere with its center at the center of mass, a level ellipsoid or the areoid, nor are there any natural reference surfaces. Since there is a need for such a surface as close as possible to the physical surface, it

is proposed that use be made of the smoothed physical surface of Mars as represented by an expansion in normalized spherical functions; the normalized expansion of Martian gravitational potential is proposed as a model of the gravity field. On this basis it was possible to construct a map of gravity variations at the physical surface of Mars with isolines drawn each 200 mgal, a map of the distribution of plumb line deflections at the physical surface with isolines drawn each 120" and a map of the elevations of the physical surface relative to a sphere R_0 = 3,389.92 km with its center at the center of mass and with isohypses drawn each 2 km. The article gives an interpretation of these maps for different zones on Mars. For example, the map of elevations of the physical surface confirms the asymmetric structure of its surface. The range of changes in gravity variations and elevations for the entire Martian surface is 4,620 mgal and 29.4 km respectively. On the basis of an analysis of the maps and other data a number of preliminary conclusions are drawn concerning the internal structure of the planet. Figures 3; references 3: 1 Russian, 2 Western.
[173-5303]

PHOTOMETRIC STUDY OF PLUTO NEAR PERIHELION. II. REFINEMENT OF ROTATION PERIOD. COLOR INDICES

Moscow PIS'MA V ASTRONOMICHESKIY ZHURNAL in Russian Vol 10, No 7, Jul 84 (manuscript received 14 Feb 84) pp 542-548

LYUTYY, V. M. and TARASHCHUK, V. P., State Astronomical Institute imeni P. K. Shternberg (Crimean Station, Nauchnyy); Kiev State University imeni T. G. Shevchenko

[Abstract] This is a continuation of an earlier study by the authors (PIS'MA V AZh, Vol 8, p 109, 1982). This new article deals with work done during 1982-1983, representing further study of brightness changes and color indices of Pluto. The observations were made in March-May 1982 and March-July 1983 at the Southern Station of the State Astronomical Institute using the same telescope as before (60-cm Zeiss reflector). The photoelectric observations of 1953-1983 gave a refined value of the photometric period of change in planetary brightness. Mean UBV brightness curves for 1980-1983 were constructed on the basis of 50 observations. A considerable reddening was discovered at the brightness maximum (phases 0.6-0.7). At the remaining phases the B-V and U-B color indices were constant. The asymmetry of the brightness curve for Pluto has increased since the 1970's. The reddening at the brightness maximum may be attributable to the existence of a "red spot" in the equatorial region characterized by a reflectivity differing sharply from that for the remaining surface. In general, it appears that observations made over a 50-year period (1933-1983) are consistent with a 124-year period in the "secular" change of brightness for this planet. Figures 5; tables 1; references 14: 2 Russian, 12 Western.
[191-5303]

LIFE SCIENCES

SECOND SOVIET-FRENCH SYMPOSIUM ON SPACE CYTOLOGY

Tallinn SOVETSKAYA ESTONIYA in Russian 1 Dec 84 p 3

[Article by V. Ovcharov (Moscow)]

[Excerpt] Results of the latest joint experiments and plans for further scientific cooperation were the focus of attention for participants in the second Soviet-French symposium on space cytology, which concluded on 30 November in Moscow. A TASS correspondent met with the coordinators of the two countries' cooperation in this field of research and invited them to comment on the results of this meeting.

I. Krasnov (Institute of Medical-Biological Problems of the USSR Ministry of Public Health):

"The first symposium on space cytology took place in Paris last year. These meetings are held within the framework of cooperation between the USSR Ministry of Public Health and France's National Institute of Public Health and Medical Research in the field of medicine and medical technology. As for the subject of the discussion, the interest in it is understandable. As a part of space biology and medicine, space cytology studies effects of space flight factors, particularly zero gravity, on the activity of life's primary units--animal and plant cells. Undertakings in this direction are of both basic and applied importance; they are already helping to solve practical problems of the medical support of space flights by humans."

M. Butey (director of the Institute of Biomedical Research of the Pierre and Marie Curie University of Paris):

"We now know that functional impairments which are observed in cosmonauts during flights are reversible; they disappear following the return to Earth. It is therefore important to develop methods and instruments which would make it possible to observe changes on the cellular level directly in orbit. Researchers in the field of space cytology have to solve a considerable number of complex problems; they have to develop automatic methods for growing cell cultures in orbit and thoroughly ascertain how zero gravity affects the structure, metabolism and functions of cells. It

is particularly interesting to study these effects for cells of the nervous, muscular and other systems of the organism.

"The first joint studies in this direction have already been made. In particular, in Moscow we discussed very interesting results obtained with the aid of the Soviet biological satellite 'Cosmos-1514.'"

FTD/SNAP
CSO: 1866/67

UDC 582.28:523

PLASMODIUM OF MYXOMYCETE AS RESEARCH OBJECT IN GRAVITATIONAL BIOLOGY

Moscow IZVESTIYA AKADEMII NAUK SSSR: SERIYA BIOLOGICHESKAYA in Russian No 2, Mar-Apr 84 (manuscript received 22 Jul 81) pp 198-209

TAIRBEKOV, M. G., BEYLINA, S. I., LAYRAND, D. B., BUDNITSKIY, A. A. and LEDNEV, V. V., Biomedical Problems Institute, USSR Ministry of Health; Biological Physics Institute, USSR Academy of Sciences, Moscow

[Abstract] The plasmodium of the slime mold Physarum polycephalum is a gigantic multicellular syncytium in which a mass of mobile, rhythmically contracting protoplasm is surrounded by a single membrane. The area occupied by a large plasmodium may be as great as 1 m^2, although its thickness rarely exceeds 1-1.5 mm. This plasmodium is capable of moving along a moist substrate and propagating through it or along the water surface, gradually sinking and forming a honeycomb structure. The protoplasm of this myxomycete is in a state of continuous movement and structural transformation. The article gives the results of laboratory studies of the morphofunctional characteristics of this slime mold carried out under modified gravity conditions on a centrifuge. It was found that this exerted an influence on the dynamics of growth and the principal morphofunctional characteristics. This work laid the basis for an experiment on the "Cosmos-1129" biosatellite during the period 29 September-14 October 1979. Five of the six samples carried aboard the satellite survived. The growth, morphology and migration of the plasmodium were studied to ascertain the influence of changes in the concentration of culture medium components and various in-flight factors. Gravitational effects were found which can be attributed primarily to energy processes in the cell. It appears that a myxomycete plasmodium can be regarded as a fundamental research object in gravitational biology for studying the effect of weightlessness on a cell. Figures 4; tables 4; references 20: 2 Russian, 18 Western.
[165-5303]

SPACE ENGINEERING

CONSTRUCTION IN SPACE

Moscow STROITEL'STVO V KOSMOSE (NOVOYE V ZHIZNI, NAUKE, TEKHNIKE: SERIYA "KOSMONAVTIKA, ASTRONOMIYA") in Russian No 9, Sep 84 pp 2-58

[Complete translation of brochure entitled "Construction in Space", by Aleksey Sergeyevich Gvamichava, candidate of technical sciences, and Vladimir Alekseyevich Koshelev, Izdatel'stvo "Znaniye," 27,650 copies, 60 pages*]

[Text] Annotation. Future development of cosmonautics assumes use of large-size constructions in space, both those of independent significance and those constituting different components of space vehicles. This brochure tells of the construction technology used for such work in orbit and the peculiarities of construction work in space. The brochure is intended for a wide range of readers interested in the modern problems of space engineering.

Introduction

Construction in space, taking into account the present-day level of development of cosmonautics, might seem to be a matter of the distant future. In our minds construction work on earth is associated with the building of long-lived structures for different purposes whose size considerably exceeds the size of the human body (construction of buildings, bridges, roads, etc.). The same applies to the future mastery of space visualized by K. E. Tsiolkovskiy, who predicted that "the dwellings and all appurtenances for them should be delivered from the earth by rockets in a folded (compact) form and assembled in space upon arrival there."

Such a direction in the mastery of space is well known to us from the space experiments now being carried out successfully. These are directed to the future creation of large orbital stations and multipurpose production complexes. Already in 1969, during the joint flight of the "Soyuz-6," "Soyuz-7" and "Soyuz-8" ships, V. N. Kubasov carried out the first welding experiments in space. In 1983 the prototype of future modular constructions, the "Cosmos-1443" heavy satellite-ship, underwent testing in the form of an orbital manned complex together with the "Salyut-7" station and the "Soyuz T-9" ship. The "Soyuz"-"Salyut"-"Progress" link-up itself presages the development of future multicomponent orbital complexes for different purposes.

* The single page appendix ("News of Foreign Cosmonautics") and the table of contents (pp 59-60) have not been translated.

However, it would be incorrect to confine the subject of space construction merely to the erection of future "space cities" or base settlements for man on the moon and planets. After all, the term "construction" is also used for the building of ships, aircraft and other transport vehicles and also the building of different types of surface stations (including also completely automated facilities). And although it would appear that at the present time space vehicles (manned ships and orbital stations, satellites and automatic probes for flight to the moon and planets) are being put into space completely ready for performance of their functions, this is not entirely the case.

The fact is that the scope of the problems solved using space vehicles (which is constantly increasing at the present time) is limited by the mass and size characteristics, which are dependent on the capabilities of the booster rockets. This problem is being solved, and rather successfully by different methods, especially by the use of the "Progress" freighters and the like, making it possible to a considerable degree to increase the volume and duration of intricate research being carried out aboard the "Salyut" orbital space stations. A solution of the problem is also being facilitated by the use of inflatable and thin-film constructions, as well as mechanical constructions deployed directly in space. The latter can be accomplished either automatically (both in response to a signal from the earth and in accordance with a program incorporated in the memory of on-board computers) or with the participation of cosmonauts (such as the case of installation of the KRT-10 radio telescope during the flight of the "Salyut-6"-"Soyuz-34" complex).

But then it turned out that in final form the construction of such complex and long-lived constructions as space vehicles is completed directly in space. And in this sense as "construction in space" we can understand the preparation for work in orbit of any space apparatus, which, being first in a compact (folded) form, then automatically deploys the panels of its solar cells, at times having an amplitude up to 20 m, extends in all directions the "whiskers" of wide-directional radio antennas and rods with different kinds of instrumentation attaining lengths of 20 m, opens up the dishes of narrowly directed radio antennas with a diameter up to 10 m, etc. It is true that the legitimacy of such a generalization is extremely debatable (although not without basis), but the use of the term "construction in space" is entirely admissible relative to so-called large-dimensional space constructions for different purposes.

In actuality, even now there are a number of urgent tasks in the mastery of space whose solution requires structures which in size considerable exceed the dimensions of the "holds" of modern booster rockets. As a result, the assembly and even the fabrication of individual elements of this kind of structures must be accomplished directly in space. Among large-dimensional space constructions we can include not only orbital complexes of a multicomponent, modular type (and in the future, also more complex structures of the type of satellite solar electric power stations and scientific-production bases for the moon and planets), but also individual components and assemblies of space vehicles also having adequately large dimensions.

In this brochure the reader will find an examination of the structural features, technology of fabrication and assembly, choice of materials and other problems involved in the space construction of large-dimensional constructions. But before proceeding to this, we will first clarify exactly what they

constitute and what their purpose is, requiring use of constructions of such enormous size. Here it is necessary to remember what functions are performed by the space vehicles themselves and by their individual instruments and systems.

Objects of Space Construction in the Coming Decades

The exploitation of space is naturally predetermined primarily by the use of space vehicles for the practical terrestrial needs of man and this direction in cosmonautics will remain fundamental during the coming decades. This also includes observations of the earth's surface by means of space vehicles in different ranges of electromagnetic radiation. Such observations are needed by meteorologists and hydrologists (in determining the state of the cloud cover, zones of generation of low-pressure areas, boundaries of melting of snows, etc.), agronomists (in evaluating the probability of yields of agricultural crops, in determining the times of their maturing, etc.), geologists (in analyzing global geological structures for the purpose of predicting mineral deposits), etc.

The traditional methods for making observations in the visible (optical) range are now being broadened by use of the radio range. Clouds are no obstacle for radio waves and in addition, due to the great penetrability of radio waves it is possible to measure the temperature of the subsoil layers and observe geological formations at depths as great as several hundreds of meters. The use of sufficiently large radio antennas aboard space vehicles will also make it possible to ascertain soil moisture content when predicting yields, the temperature of sea water, wind velocity, and even the depth of the snow and ice cover.

Recently much attention is being given to the use of artificial earth satellite systems for the needs of communication, television broadcasting and navigation, for determining the coordinates of ships and aircraft which have experienced wrecks or disasters, etc. It is noteworthy that among the countries of the world the Soviet Union was the first to have an operational national satellite communication system ("Orbita") and an operational system for direct television broadcasting to the receivers of subscribers ("Ekran"). The first experimental satellites ("Cosmos-1383" and "Cosmos-1447") for the international satellite system for search for and rescue of ships which have experienced wrecks or disaster "COSPAS" were also launched.

This direction in the development of cosmonautics involves, in particular, an improvement in the on-board radio equipment of space vehicles (satellites). And in the more distant future the use of large on-board antennas and relay apparatus will make possible not only a considerable increase in the number of communication channels, but also the use of similar satellite systems for such purposes as control of the transport of freight, routine transmission of postal communications, personal space radio communication, etc.

Large radio antennas are also needed aboard future orbital space stations, for example, for higher-quality relaying of signals to the earth from spacecraft exploring distant regions of the solar system. In general, in the study of distant objects in the solar system (planets, their satellites, comets) in their

immediate neighborhood it is important to have high-speed transmission of telemetric information to the earth, and this also involves the use of sufficiently large on-board radio antennas.

The study of astronomical objects has always occupied a significant place in the scientific research carried out with space vehicles. However, since information concerning objects situated beond the limits of the solar system (stars, pulsars, galaxies, quasars) is concentrated in their electromagnetic radiation, the principal instruments for all astronomical satellites are all kinds of devices for the reception of this radiation.

Here it must be said that the earth's atmosphere is opaque for most ranges of the spectrum of electromagnetic radiation. Even in the traditional optical range, in which astronomical observations have been made for several millenia, the earth's atmosphere constitutes considerable interference because the turbulent air movements distort the image and limit the angular resolution of the observed objects. Accordingly, significant progress in astronomical research is attained when instruments are put beyond the limits of the earth's atmosphere.

The use of large radio and optical telescopes for these purposes will naturally increase the value of such observations. In addition, radioastronomical observations with a very high angular resolution are being favored by the development of space radiointerferometers, that is, systems of two or more radio telescopes with one or two of them being in space. The use of gamma and X-ray telescopes is also assuming special importance. For these instruments the greater the receiving surface, the more productive are the observations of astronomical objects in this range.

Thus, different directions in space research require the outfitting of space vehicles with different kinds of devices detecting electromagnetic radiation. The efficiency of operation of these instruments (primarily sensitivity and angular resolution) is increased with an increase in the area of the receiving elements. However, the fabrication of high-quality mirrors for optical telescopes directly in orbit for the time being is an insoluble problem*, whereas the assembly of even large radio antennas in space is an entirely feasible task. For this reason it is precisely radio antennas which in the near future will be in the widest use and at the same time feasible to construct with large-size elements among the various possible types of space structures.

Figure 1 shows the principal parameters of space radio antennas in relation to their purpose. It can be seen that the use of such antennas in an artificial

* It is true that recently projects for terrestrial multimirror optical telescopes with a diameter up to 25 m or more have been discussed widely in the press. A 10-m optical telescope in Arizona, used for the most part for observing optical flares induced in the atmosphere by gamma radiation of superhigh energies from cosmic sources, may serve as a prototype of such telescopes. In the future space multimirror (mosaic) optical telescopes will possibly come into use, but for the time being single-mirror telescopes are considerably superior to multimirror telescopes.

earth satellite orbit is extremely promising for antennas measuring more than 30 m. A good many projects have now been proposed for large space radio antennas for different fields of application, including for radio communication, navigation, study of the earth from space and astronomical research. The peculiarities of design, technology of fabrication and other similar problems are now being solved to a great extent with allowance for existing modern on-board radio antennas which although they are lesser in size, nevertheless are quite large (up to 10 m).

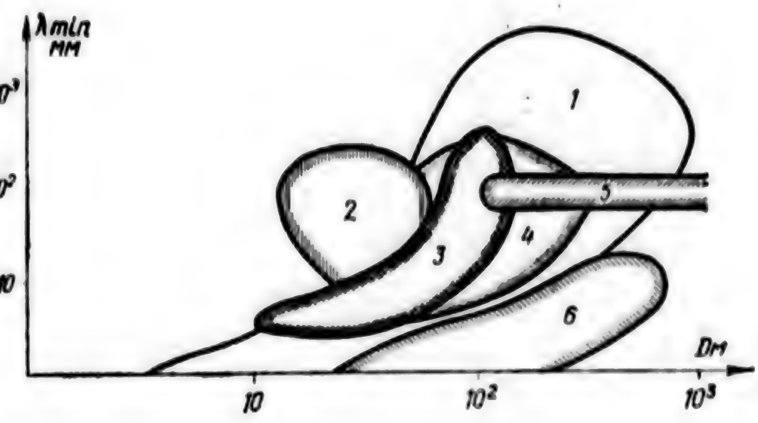

Fig. 1. Minimum wavelength and diameter of mirror for space antennas of different types (1 -- radioastronomy, 2 -- interferometry, 3 -- radiometry, 4 -- space relay apparatus, 5 -- energy transfer in satellite solar electric power stations, 6 -- search for extraterrestrial civilizations).

However, the reader can get the impression that space antennas will perhaps be the only large-dimension elements of space vehicles in the coming decades. This is far from the case. Gamma and X-ray telescopes, which, to be sure, have too narrow a field of application, will also have impressive dimensions among the considered receivers. But in almost every space vehicle there are elements whose efficiency of operation is also dependent to a considerable degree on size. Reference is to solar cells ensuring the necessary energy supply to systems of space vehicles and already having a useful area of about 40 m^2, with the length of the deployed panels being up to 20 m.

In modern and planned space vehicles the deployment of solar cells of different types (panel, rolled, etc.) occurs automatically. However, the in-orbit construction of quite large large-dimensional solar cells will require man's direct participation. In this connection the work of Soviet cosmonauts in late 1983 and in 1984 in the installation of additional solar cells in open space for the orbital station "Salyut-7" is extremely promising.

It is noteworthy that both types of large-dimensional constructions (radio antennas and solar cells) constitute the basic elements of future satellite solar electric power stations, the projects for which are being discussed in depth in the scientific literature. These space structures have already been discussed repeatedly on the pages of brochures in this series (for example, see: S. A. Khudyakov, KOSMICHESKIYE ENERGOUSTANOVKI (Space Electric Power Plants), Moscow, 1984). Here we will recall only the dimensions of the

principal elements of satellite electric power stations: area of solar cells about 100 km^2; diameter of antenna for microwave radiation for transmission of energy to the earth -- about 1 km.

The realization of projects for satellite solar electric power stations will become possible no sooner than in the next century, the same as the realization of other grandiose projects such as the putting of gigantic mirrors into orbit for the direct reflection of the energy of solar radiation to the earth. However, possibly as the 20th century passes into the 21st experimental automated complexes for the production of different substances and materials will begin to function in space. Technological experiments are now an indispensable part of the research carried out by Soviet cosmonauts aboard the "Salyut"-"Soyuz" scientific research complex. Now the task is the creation of automated space factories of industrial significance in orbit.

Space structures of the satellite solar electric power station type, orbital factories and also, for example, space "shipyards" for the assembly and launching of spaceships, although they do not require the direct participation of man on board, do have provision for the work of the cosmonauts in their assembly, adjustment, regulation and repair. In other words, their construction, like that of large orbital scientific stations, is already impossible without corresponding construction work with the participation of specially trained cosmonaut construction workers.

The technology for the fabrication of all these space structures of the next century is naturally much more complex than is the case of the space deployment of large-dimensional structures of the radio antenna or solar cell type. Nevertheless, the construction of both in space involves a considerable range of general problems (design peculiarities, construction technology, construction materials, etc.) and therefore the examination in the sections which follow of the problems involved in the construction of space antennas, as well as other large-dimensional space constructions of the immediate future, in one way or another relates to the problems involved in space construction of more massive structures of the next century.

Types of Large-Dimensional Structures

The construction and operation of large-dimensional space structures are accomplished under conditions differing considerably from terrestrial conditions. Accordingly, the fundamental construction principles and technology which it is proposed be used for these purposes also differ from terrestrial principles. True, in the space structures which have been built and which are being developed in most cases, as in terrestrial construction, use is made of mechanical constructions.

This is possibly attributable to the inertia of thought and the relatively brief time which is allocated for the development of large-dimensional space structures. The traditions of terrestrial construction have developed over the millenia, but space construction has a history of only a few decades (if the launching of the first satellite is taken as a point of departure). In addition, as is well known, in designing work it is always easier to apply already known

methods to new conditions than to work out fundamentally new methods corresponding better to these conditions.

In a general case, however, the large-dimensional space structures developed at the present time can be classified into the following types on the basis of the construction principles applied:

mechanical constructions in which maintenance of a given configuration both in the course of construction and during the period of operation is ensured due to the rigidity of framework components;

pneumatic (inflatable) constructions whose expansion and the maintenance of whose form occurs due to excess internal pressure;

centrifugal systems whose deployment and maintenance of whose form will take place due to the centrifugal forces arising during the rotation of the structure about its center of mass;

electrostatic constructions, the maintenance of whose configuration is accomplished due to electrostatic (or magnetic) forces.

Combinations of these types are possible, as is the future appearance of fundamentally new construction principles.

All space structures differ appreciably with respect to the methods for their construction. Here the classification of structures in the following groups is admissible: completely constructed on earth and put into orbit in already finalized form; completely constructed on earth but put into orbit in packaged form and automatically deployed upon reaching the stipulated orbit; assembled in orbit from ready-made components or their intermediate stages delivered from the earth; constructed in orbit from raw materials delivered there.

Until recently it was for the most part constructions of the first group which have been used; these have been discussed in adequate detail in the popular science literature (for example, see Ye. I. Popov, AVTOMATICHESKIYE KOSMICHESKIYE APPARATY (Automatic Space Vehicles), Moscow, 1984). But during recent years space vehicles have begun to carry radio antennas whose structure is characteristic of the second group.

Mechanical constructions of space antennas. Most of the space antennas which have been developed and planned are of the so-called dish type. They are quite universal and from the technical point of view their structure is more suitable for space conditions. In such antennas the received radio radiation is collected in a focal zone by means of a main dish of parabolic or spherical configuration. The radio radiation flux reflected by the main dish is then incident in the receiver either directly (single-dish system) or after re-reflection from a secondary dish of lesser size (two-dish system). The receiver or secondary dish is placed in the focal zone, being connected to the main dish by means of mechanical supports.

Almost all the automatically deployed dish antennas already used in space have been of the umbrella type. Their dish part consists of radially arranged stiffening ribs to which is attached a reflecting surface fabricated from stretchable metallized films, fabrics or mesh. The umbrella construction is evidently optimum for small vehicular antennas, those operating only at sufficiently long wavelengths. The latter is attributable to the fact, as shown by computations, that the deviations of the real reflecting surface from the theoretical surface are great in this case.

The largest antenna of the umbrella type, and the most interesting in its design was that mounted on the American satellite "ATS-6." The dish of this antenna in folded form had a diameter of 2.5 m and in deployed form a diameter of 9.1 m. It was rigid in its central part (measuring 2.2 m), to which 48 flexible ribs were attached, on which was stretched a reflecting surface of metallized dacron. The ribs of ultrastrong aluminum alloy in section formed an unclosed thin-walled ellipse and with folding they were turned in such a way that their cross sections became segments of a straight line and in such a form the ribs were wound on the rigid central part of the antenna.

The receiving system of the antenna at the focus of the dish, situated in a container, was attached to the dish by means of a nonfolding girder support.

Among the shortcomings of space antennas of this type are the relatively low rigidity of the dish and the great deviations of the real surface from the theoretical surface. In these antennas the material stretched between the ribs is situated along the cylindrical surface and deviations from the theoretically stipulated form of the dish increase with an increase in the distance between the ribs. Plans are now being made for a space antenna of the umbrella type with a diameter of 30 m and evidently this size is close to the limit for such constructions. However, since efficiency of operation of antennas of the umbrella type is attained only under the condition $D/\lambda \leq 200$ (here λ is the wavelength, D is antenna diameter), accordingly the minimum working wavelength for an antenna with a diameter of 30 m will be 15 cm.

The shortcomings characteristic for antennas of the umbrella type can be eliminated to a considerable degree in constructions of the spatial rod girder type. In particular, so-called two-lattice constructions have come into wide use; these are structural beams consisting of two latticed ("cellular") domes joined to one another by rigid diagonal rods of identical length. The domes themselves consist of the same rigid rods, but with tension joints in the middle allowing them to be folded. For example, in an antenna with domes of triangular cells (Fig. 2) six folding and three diagonal rods will converge at each junction.

The rods are attached to the framework junctions by means of cylindrical joints. With folding of the framework the folding rods are folded in the middle and are simultaneously turned in the joints. The diagonal rods, however, become vertical, also turning in these junctions. As a result the junctions converge and the framework fits in a compact package.

A reflecting surface, usually fabricated from a metallized mesh, is attached to the junctions of the working grid. In our case, with triangular cells

(see Fig. 2) such a reflecting surface constitutes a system of plane triangles. In accordance with radioengineering requirements the side of a triangle must not exceed the value $(D/\lambda)^{1/2}$. Depending on the value of the D/λ ratio and the operational conditions the diameter of the dish in folded form is 10-40 times less than in a deployed form.

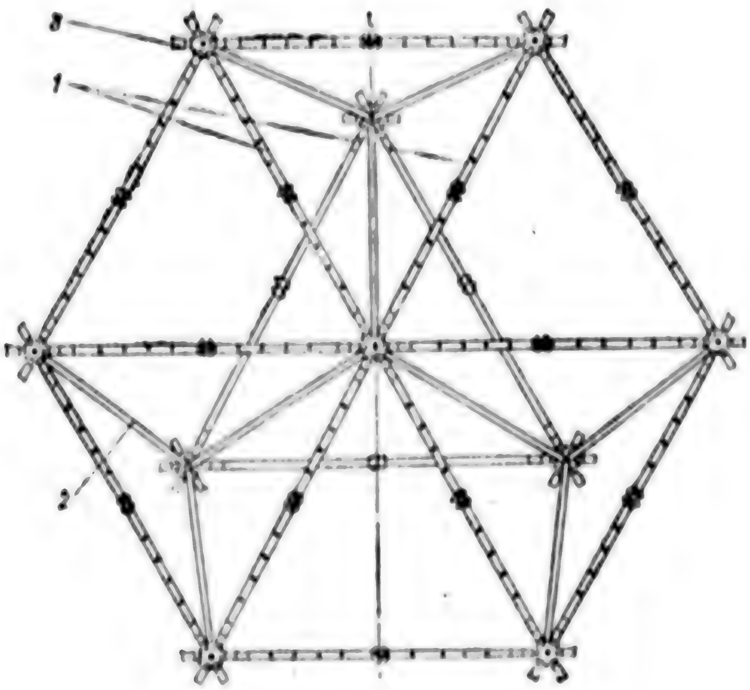

Fig. 2. Diagram of construction of spatial rod girder type with two domes of triangular elements: 1) folding rods, 2) diagonal rods, 3) framework junctions.

Constructions of the spatial rod girder type have undergone corresponding testing under terrestrial conditions. In particular, a 5-m foldable antenna was subjected to a full program of mechanical and radioengineering tests which revealed good performance and a high reliability of such a construction. It can evidently be expected that in the immediate future they will also begin to function in space.

KRT-10 space radio telescope. During recent years a modification has been developed which somewhat improves some characteristics of space antennas of the type just considered. The basis for this modification was the replacement of all the folding rods by thin taut flexible cables. The overall geometrical layout of antenna construction can remain the same as in the case considered earlier (Fig. 3).

In these antennas the deployment of the framework and the tightening of the thin flexible cables occur due to springs mounted at the junctions of the upper and lower grids. The deployment mechanism includes a guide, rigidly attached at a juncture of the framework and also (moving along it under the

influence of a spring) a bushing and three auxiliary rods connected by a joint to the bushing and three diagonal rods. With deployment of the antenna the spring moves the bushing with the auxiliary rods along the guide and separates the diagonal rods.

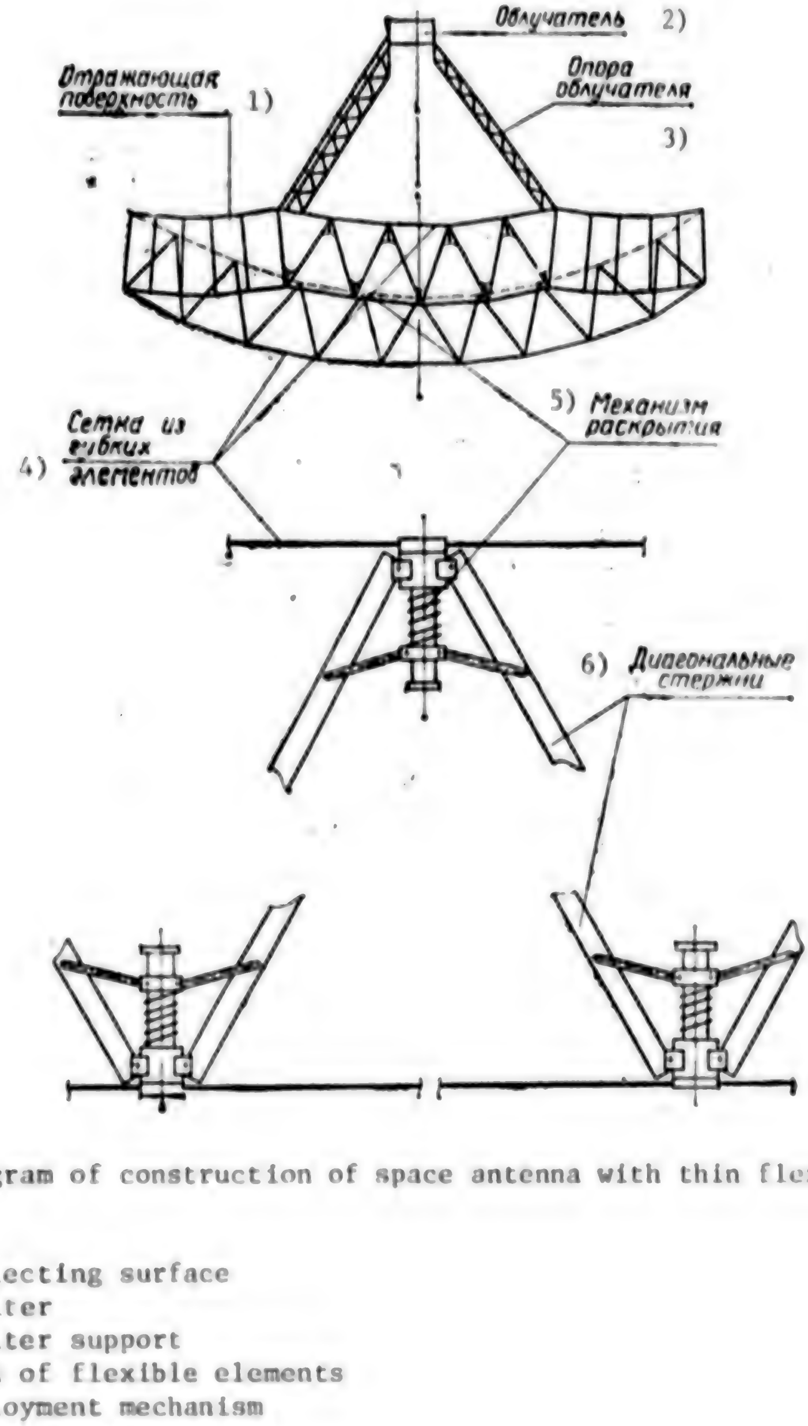

Fig. 3. Diagram of construction of space antenna with thin flexible cables.

KEY:

1. Reflecting surface
2. Exciter
3. Exciter support
4. Grid of flexible elements
5. Deployment mechanism
6. Diagonal rods

Such a type of construction of space antennas is rather simple to fabricate and the required curvature of the reflecting surface is ensured by the careful choice of the corresponding lengths for the thin flexible cables. A construction with flexible elements also allows more compact packing (it is true that its deformability is greater).

A 5-m antenna which underwent testing under terrestrial conditions and a 10-m antenna tested initially under terrestrial conditions and then mounted on the "Salyut-6" orbital station had the considered construction. This 10-m space radio telescope (KRT-10) was delivered to the station in July 1979 using the "Progress-7" freighter. Due to the small volume allocated in the "Progress-7" for the KRT-10, the latter was therefore broken down into three individual blocks: main dish, focal container with exciter and three extensible supports and a mechanism for attachment of the antenna to the station.

The main dish of the KRT-10 was a hexagonal section from a paraboloid of revolution. The dish framework consisted of diagonal rods (from aluminum alloys) with a section 6 x 12 mm and thin cables with a diameter of 1 mm. The junctions were made of aluminum alloys and the springs from high-strength steels. The reflecting surface was a specially developed "knitted" mesh curtain of fine metallic wires with a diameter of 50 μm. The mass of the dish was 65 kg and in a folded form it was a hexagonal prism with a maximum measurement at the base of 0.5 m and a total length of 0.9 m.

The antenna exciters were attached on the body: four horns for operation at a wavelength of 12 cm and a spiral exciter for operation at a wavelength of 72 cm. Also situated on the body was a focal container, within whose pressurized compartment there were high-frequency amplifiers of radiometers and a heat-regulating system. The focal container was joined to the dish by means of three folding supports. In deployed form each support was a trihedral form with a length of 5 m (in folded form the length of the support was 27 cm). The mass of the supports was about 7 kg.

Along the supports and toward the center of the framework construction there were cables connecting the focal container apparatus and some sensors situated on the antenna to the apparatus mounted in the working compartment (low-frequency blocks of radiometers, time block and control panels). The total mass of the KRT-10 was 300 kg.

The Soviet cosmonauts V. A. Lyakhov and V. V. Ryumin carried out docking and mounting of all the KRT-10 blocks, attached it to the station transfer hatch and carried out a preliminary checking of interaction of its components. On 18 July 1979 the "Progress-7" freighter departed from the station, after which the KRT-10 radio telescope was automatically extended and deployed. After it was put into operation adjustments were made (tie-in of the antenna rays to the axes of the "Salyut-6" station) and the directional diagram was determined.

These measurements were made in the process of rotating of the entire station. They were accomplished during registry of the radioemission of Crab nebula (source Cassiopeia A), the sun and a surface radio source. The results of the measurements were close to the computed values. In the process

of KRT-10 operation astrophysical and geophysical investigations were made. It is also interesting to note the observations of Etna volcano, which was active at the time.

The functioning of the KRT-10 apparatus continued up to 9 August when the space radio telescope was separated from the "Salyut-6" station. In the course of separation four thin cables caught on a protruding part of the station and the cosmonauts had to emerge into open space and cut them.

Prospects for development of mechanical constructions. Theoretical and experimental investigations of space antennas having a construction of the spatial rod girder type indicated that they are entirely reliable and meet all operational requirements. Such constructions of space antennas have an adequate rigidity and can ensure an accuracy in adherence to the form of the reflecting surface necessary for operation in the centimeter range. Computations show that the ratio of mass of the space antenna to the area of dish deployment for constructions of the spatial rod girder type, depending on operating conditions, varies from 0.2 to 1.0 kg/m^2.

The tendency in development of space antennas is such that in the future there will be a need for the largest antennas possible, operating at shorter wavelengths. However, the maximum dimension of automatically deployed space antennas operating in the centimeter range cannot exceed 200 m and for space antennas operating in the millimeter range the maximum dimension of self-deploying constructions is even less. The fact is that in the latter case both errors in fabrication and deformation of the framework and the mechanical properties of the reflecting surface of the dish, fabricated from mesh or film, already exert a strong effect.

It is true that this can be avoided if the reflecting surface is fabricated from adequately rigid panels with an accuracy in deviations of the real surface from the theoretical surface on the order of 0.05 mm. The dimensions of the panels, determined by the mass and size possibilities of the used rocket-space transport vehicles, evidently cannot exceed several meters (according to estimates, 4.5-5.0 m). Unfortunately, it is quite difficult to make such a construction of space antennas self-deploying and therefore the construction of space antennas for short wavelengths even with dish dimensions of 20-30 m will require the implementation of assembly operations in orbit with the participation of man (Fig. 4).

The volume of this assembly work can be substantially reduced because with dish dimensions less than 200 m the framework itself can be made automatically deployable. In addition, the installation of panels on the framework can be accomplished using specially designed automatic apparatus controlled by man. The dimensions of the framework cells must correspond to the dimensions of the panels and the panels themselves, made, shall we say, in the form of a hexagonal section from a paraboloid of revolution, will be attached at three points to the framework junctions.

The main difficulty in the construction of such large-dimensional space antennas for short wavelengths is that the deformation of the framework considerably exceeds the tolerance for accuracy of deviation of the real

reflecting surface from the theoretical surface and therefore automatic regulation is required. The system for such regulation should include a logic block, means for monitoring and compensating errors. The latter can be accomplished by moving the panels relative to the framework, for which each panel is attached to the framework by means of three pins moving along the normal to the reflecting surface. So-called linear motors have now been developed which are capable of ensuring movements to a fraction of a micrometer, but an important problem which remains is an adequately routine monitoring of the surface.

In the construction of space antennas whose dimensions exceed 200 m, and now there is a need for antennas measuring 1 km or more (for example, for satellite solar electric power stations), it is already necessary to assemble a supporting framework. In assembling the framework it is possible to use folding, automatically deployed modules, making it possible to reduce in-orbit assembly operations to a minimum. Moreover, this method for assembling space antennas affords a possibility for adding-on to an already operating antenna. Prediction of development of rocket-space transport vehicles indicates that the size of this standard module will be 200 m. According to estimates, the framework for such a module, constructed in the form of a spatial girder construction and fabricated from composition materials, can have a mass of about 4 tons. The maximum dimension of a space antenna which can be assembled in orbit from modules of this type is determined by the rigidity and mass of the module and also by operating conditions. However, the maximum rigidity for a stipulated mass is set by the maximum construction height of the structure. Again, taking into account the predicted capabilities of rocket-space transport, the structural height of the considered construction of the spatial rod girder type is estimated at several meters (10 m with a rod measuring 15 m).

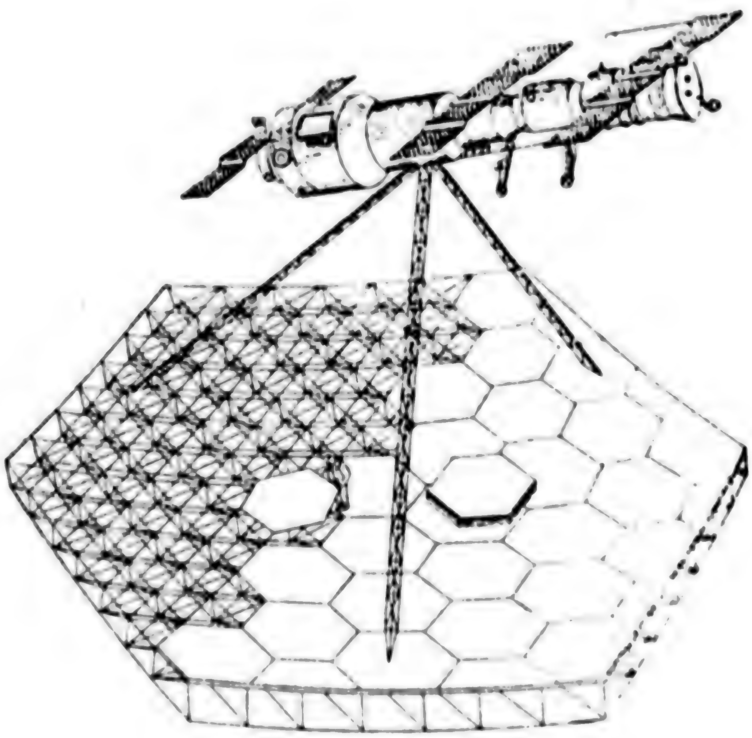

Fig. 4. Assembly of space antenna measuring 30 m for operating in range of short wavelengths.

In general, for each definite orbit there is a particular maximum size of space antenna because an increase in dish diameter involves a marked increase in structural mass. For example, computations show that in a geostationary orbit the maximum diameter of a space antenna dish is about 10 km.

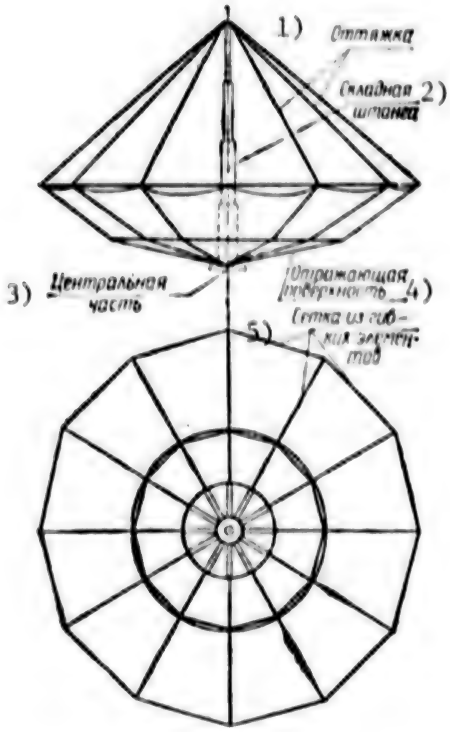

Fig. 5. Diagram of centrifugal construction with flexible ribs.

KEY:

1. Guy
2. Folding shaft
3. Central part
4. Reflecting surface
5. Grid of flexible elements

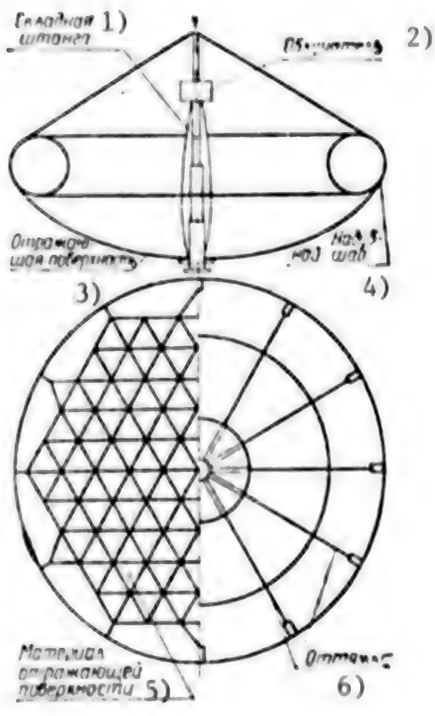

Fig. 6. Diagram of inflated construction of space antenna.

KEY:

1. Folding shaft
2. Exciter
3. Reflecting surface
4. Inflatable sphere
5. Material of reflecting surface
6. Guy

Other types of constructions of space antennas. Mechanical constructions therefore make possible the construction of sufficiently rigid and precise frameworks for antenna structures in space. And although they are relatively massive and although their assembly in orbit is rather complex, in the coming decades most space antennas will be built on the basis of mechanical constructions. However, projects for other types of constructions for space antennas have been proposed.

Centrifugal constructions. Many designs have appeared during recent years in which the configuration of space antennas is maintained by means of centrifugal forces. In actuality, since no drag exists in space, it is quite easy to maintain a constant velocity of rotation of bodies there. Moreover, in such constructions temperature deformations are considerably less than in mechanical constructions because due to the rotation the structure will be more uniformly heated by the sun's rays.

The framework of a space antenna of this type can be constructed in the form of a network of flexible fibers having a radial-circular layout (Fig. 5). The concentration of mass falls on the junction points of the fibers; the framework is attached to a central shaft. All the framework junction points are situated on a paraboloid of revolution and the reflecting surface is attached to these junctions. Its central part should be opened up in the form of a cone, whereas the remaining part is opened up in the form of a paraboloid of revolution. Small flexible cables pass along the edge of the entire antenna, and also where the cone and paraboloid are joined.

The rotating constructions of space antennas allow very compact packing and make it possible to build quite light dishes with a ratio of antenna mass to to the area of dish deployment 0.20-0.50 kg/m^2. Such constructions can be used for space antennas of very large dimensions and a project is now under consideration for constructing a space antenna with a diameter of 2 km for operation in the meter range. However, a number of serious problems arise in the development of rotating constructions for space antennas and their solution is extremely difficult.

Among these problems is the development of the required motors, reducers and bearings for long-term operation in open space and the development of systems which would ensure the synchronous deployment of the construction and the prevention of entanglement of the cables. The rigidity of the rotating construction and the attainable accuracy of the reflecting surface are substantially lower than in mechanical constructions. Major complexities arise in solution of the problems involved in the fabrication of elements both under terrestrial conditions and directly in orbit.

The fact is that such constructions are very sensitive to the technological inaccuracies of fabrication. The technological errors in them are approximately an order to magnitude greater than in mechanical constructions. Moreover, during terrestrial testing it is very difficult to use systems for simulating weightlessness due to the presence of drag and gravity. In orbit still other errors appear due to the wobble of the central axis of the construction as a result of imbalance of its mass.

Definite difficulties evidently also arise in control of the space antennas of a rotating construction due to the presence of gyroscopic effects.

Inflatable constructions. During recent years a number of projects for space antennas have appeared in which provision is made for an inflatable construction. The framework of such an antenna can be obtained in the form of an inflated torus to which reflecting and auxiliary surfaces fabricated of synthetic films are attached (Fig. 6). The two surfaces form a closed volume in which the creation of excess pressure ensures surface tension. The exciter is attached to the torus by means of a system of guy wires.

A network of quartz fibers can be attached to a reflecting surface fabricated from a metallized film and having the form of a paraboloid of revolution or a sphere for maintaining the geometrical dimensions and reducing temperature deformations. In this case the basic accuracy will be ensured precisely by this network. With an extended network the distortions of the reflecting surface as a result of technological errors in fabrication should be of the same order of magnitude as in rotating constructions.

Inflatable constructions of space antennas can be packed very compactly and are characterized by a small ratio of the mass of the structure to the area of deployment of the dish, equal to from 0.15 to 0.25 kg/m^2. But in the fabrication of inflatable structures technological difficulties arise because the envelope has closed cavities and therefore the seams must ensure excellent air-tightness. In addition, in the operation of a space antenna of such a construction there must be precise adherence to the ratio of pressures within the torus and within the main volume of the antenna.

The principal shortcoming of inflatable space antennas is that they lose their function when they are penetrated by meteoroid bodies. However, in the future inflatable constructions of space antennas may come into extensive use if foaming and self-hardening materials with suitable characteristics are developed and put into use.

Electrostatic constructions. Recently designs of space antennas were proposed which are virtually free of the shortcomings of inflatable constructions but at the same time retain all their merits. In these structures the maintenance of form is achieved due to the force of interaction of electrostatic charges. Estimates of the energy expenditures on the maintenance of electrostatic charges show that a dipole scheme is the most economical. In such a scheme charges of opposite signs are induced on the interacting surfaces. In such constructions it is extremely attractive to construct dishes without rigid elements, which would make them simple to build, light and packable in very compact form.

However, the forces of interaction of electrostatic charges are small and decrease inversely proportionally to the square of the distance between the interacting surfaces on which the charges have been induced. Investigations have been made which show that with potentials on the order of 10^6V which are really attainable at the present time the maximum size of spherical and elliptical space antennas of such a design will not exceed 20 m. However, in constructing space antennas of a greater size it is necessary to use a rigid

ring to which a reflecting surface of metallized film or metallic grid (designed in the form of a paraboloid of revolution or sphere) is attached.

As the reflecting surface it is possible to use an auxiliary conical surface of metallized film, applied in individual sections, separated by radial and annular openings. A charge of one sign is imparted to the reflecting surface, whereas a charge of the opposite sign is imparted to the auxiliary surface so that coming close to one another the surfaces will draw apart. In principle the accuracy of the reflecting surface in this case will be of the same order as for an inflatable structure, but in the presence of systems controlling the surface accuracy it is very simple to regulate it. For this purpose on each sector of the auxiliary surface it is possible to change the charge in such a way that the deformations caused by change of the electrostatic forces compensate the distortions of surface form.

The two surfaces can be attached to the same rigid ring, but as indicated by computations, in order that they not come into contact the width of the ring must be 0.050-0.075 the antenna diameter. It is possible to have a construction with two rigidity rings (for example, folding), connected to one another by tension wires (Fig. 7). The exciter can be attached to a shaft, one of whose ends rests at the vertex of the conical surface, whereas the other is connected to this ring by guys.

There are definite relationships between the accuracy in fabricating the reflecting surface, number of isolated sectors on the auxiliary surface and a minimum wavelength. With these relationships taken into account, a space antenna with a diameter of 30 m has now been developed for operating in the centimeter range; projects for space antennas for the millimeter range are being discussed; attempts are even being made to develop optical antennas of such a design. It must be said that due to the presence of the rigidity rings the density of packing of space antennas of the considered type will be almost the same as for mechanical constructions, but the ratio of antenna mass to the area of dish deployment is somewhat less: about 0.2-0.6 kg/m^2.

In developing space antennas of the electrostatic type it is also necessary to solve many problems with respect to both the technology for the fabrication of surfaces and with respect to control of the reflecting surface and its regulation. However, the constructions of this type are considered more promising than rotating or inflatable constructions. The maximum size of space antennas of both the electrostatic and mechanical types, however, is about 200 m.

Designs of solar cells. The solar cells used in space vehicles have been repeatedly discussed on the pages of brochures of this series (for example, see A. G. Iosif'yan, ELEKTROTEKHNIKA V KOSMOSE (Electrical Engineering in Space, Moscow, 1979; S. A. Khudyakov, KOSMICHESKIYE ENERGOUSTANOVKI (Space Power Plants), Moscow, 1984). Accordingly, here we will discuss them briefly and only from the point of view of design features.

In principle solar cells of space vehicles can have all the types of constructions which were enumerated earlier for large-dimensional structures.

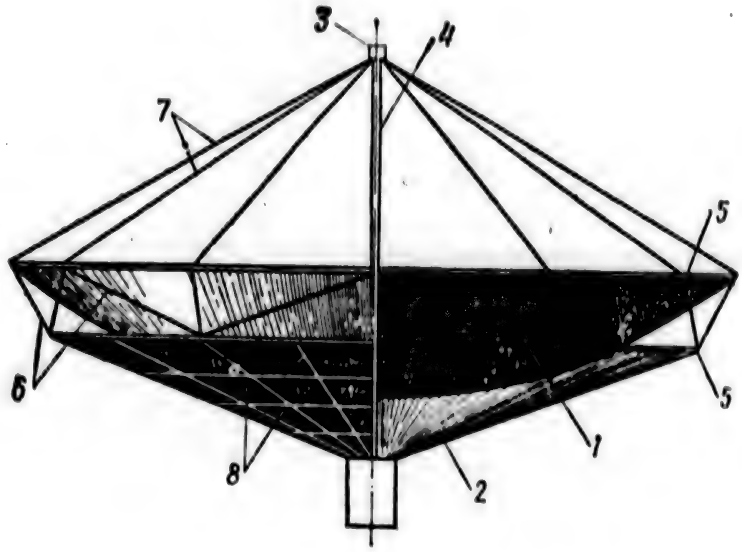

Fig. 7. Design of electrostatic construction: 1) reflecting surface, 2) auxiliary surface; 3) exciter; 4) shaft; 5) rigidity ring; 6) tension wires; 7) rollers; 8) electrodes.

However, the development of solar cells on the basis of constructions in which the form is maintained by electrostatic forces involves enormous difficulties, especially in relation to the possibility of an electrostatic breakdown. The designs of solar cells which have now been developed are for the most part of the mechanical type, although many projects have been proposed which are based on the pneumatic (inflatable) or centrifugal types of constructions.

Automatically deployed solar cells of the panel type are now usually employed in space, that is, those which constitute a modification of mechanical constructions. In cosmonautics much attention is being given to automatically unfolding or deployable flexible (especially roll-type) solar cells. They can be of very different design: there are proposals for such cells of the mechanical and inflatable and centrifugal types.

The use of rigid panels for the assembly (deployment) of sectional solar cells is extremely limited (as in the case of use of rigid panels for space antennas which we examined earlier) by the dimensions of the panels, determined by the capabilities of the rocket-space transport vehicles. The advantage of flexible solar cells here is unquestionable since, put into orbit in very compact form (for example, in rolls), by means of rods or other adaptations they can then be extended to far greater length on extensible frames (mechanical constructions) or simply deployed under the influence of centrifugal forces (centrifugal constructions) and the forces of internal pressure (inflatable constructions). In the latter case it is usually proposed that the accordion principle be applied, but other extremely exotic solutions are also possible (for example, like an inflated balloon of sufficiently large size).

The prospects for flexible solar cells are also tied in to the use of a film backing with a thickness of several tens of micrometers to which phototransducers are attached. A honeycomb sheet backing of an aluminum alloy (thickness

of supporting sheets 0.12-0.15 mm, thickness of honeycomb 4-5 mm) is used for modern solar cells of the panel type. In the more distant future it is proposed that lighter panel solar cells with a backing of sheet composition material (on the basis, for example, of carbon fibers) and a filler of super-light film be developed.

Moreover, flexible (roll type) solar cells with radiation hardening of the film substrate (backing) will naturally have a far lesser mass than solar cells with a rigid supporting construction of the panel type. However, it should be noted that the development of film photoelectric transducers involves a number of difficulties, as a result of which the possibility of using amorphous monocrystals for these purposes is now being considered. A shortcoming of flexible solar cells is their extremely low rigidity and accordingly in the development of future solar cells it will be common to have recourse to a combination of different types of constructions.

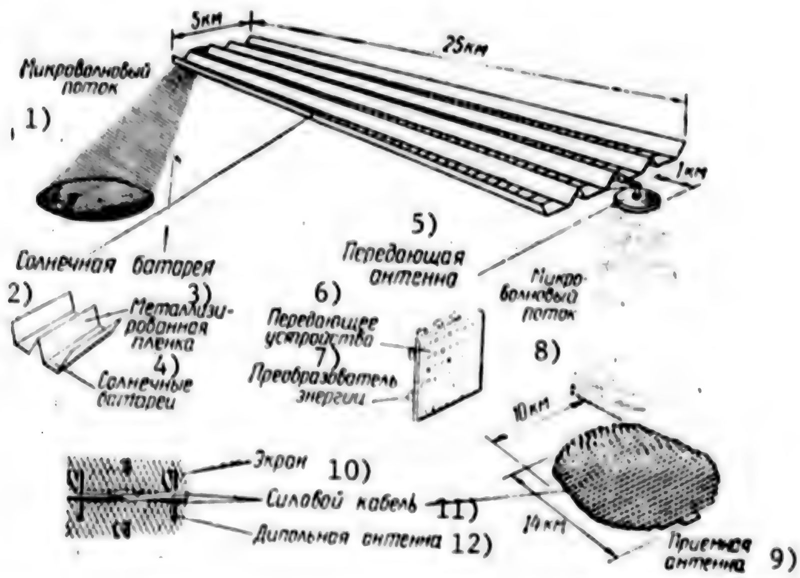

Fig. 8. Diagram of interaction of main elements of satellite solar power station.

KEY:

1. Microwave flux
2. Solar cell
3. Metallized film
4. Solar cells
5. Transmitting antenna
6. Transmitter
7. Power tranducer
8. Microwave flux
9. Receiving antenna
10. Screen
11. Power cable
12. Dipole antenna

For example, flexible (roll-type) solar cells can be stretched on a rigid construction of the frame (panel) type, deployed automatically under the influence of centrifugal forces. One edge of each such flexible panel can be rigidly connected to the side wall of the space vehicle along a generatrix which is

parallel to the axis of rotation, whereas the end elements of mass concentration will be attached along the free edge. Other variants are also possible, including constructions of spatial rod girders.

The construction of gigantic space solar cells of an enormous area, as, for example, in the construction of satellite solar power stations, requiring an area of the solar cells of about 100 km^2 for these purposes (Fig. 8), can be accomplished only with assembly work carried out directly in space (in particular, using robots). Usually the projects for satellite solar power stations provide for the use of solar cells on a girder platform, each element of which is a tetrahedral, trihedral or cylindrical (the latter is called a geodesic beam) latticed construction girders.

The joining of the girders with one another can be accomplished from a special orbital station supplied with several manipulators having a set of interchangeable tools. The control of operation of such a station requires several men; the assembly work itself will be accomplished with automatic girder assemblers. Provision is also being made for automation of the necessary operations for the installation of the solar cells proper and the heat engines on the girder.

Space platforms: purpose and designs. As indicated by theoretical investigations the use of space platforms (especially in a geostationary orbit) of both relatively small size and also large-scale, in addition to the just considered variant for the needs of satellite solar electric power stations, has a number of advantages over the use of ordinary satellites of different kinds. Accordingly, during recent years a great number of projects have appeared for multipurpose space platforms which can be used for the needs of communication, astronomy, meteorology, navigation, study of natural resources, etc.

Most of the projects are devoted to solution of communication problems. The placement of a great amount of equipment on a single space platform will make possible a considerable decrease in expenditures on the development of a space radio communication system.

Such platforms, in addition to the principal instrument blocks, should serve as a base for power supply, orientation, stabilization and heat-regulating systems. They can also be supplied with mooring apparatus for the approach of spaceships, pressurized compartments for housing people, as well as manipulators and other devices for assembly and repair work. Incidentally, the placement of a large amount of different kinds of apparatus on platforms will considerably simplify the implementation of regulation and repair work.

The design decisions and technology for the construction of platforms in space can be different. It is true that a mechanical type of construction (Fig. 9) is used in all existing projects and at the present time there are not even any acceptable ideas concerning the development of space platforms on other principles. According to cited estimates, an automatically deployed platform measuring 200 x 200 m can be put into orbit in a single launching. However, for the creation of the space platform as a whole it is still necessary to carry out assembly work in orbit which to a great extent will be automated.

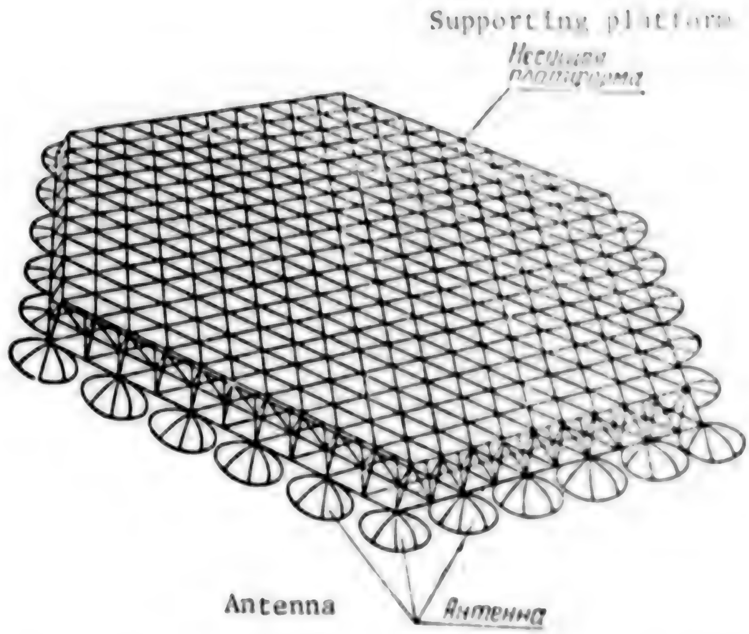

Fig. 9. General appearance of space communication platform.

In the case of space platforms measuring more than 500 m it will be more advantageous to accomplish assembly of the supporting framework from elements delivered from the earth because in this case a more compact packing of the platform elements can be attained, as well as a lesser mass of its construction. The latter, in addition, can be simplified somewhat by the elimination of hinged joints in it. According to the estimates of specialists, parts for the assembly of a space platform measuring 1 x 1 km can be put into orbit in a single launching.

In most proposals for space platforms the construction of the supporting framework is of tre spatial rod girder type. Constructions of such a type have high strength and ıigidity qualities with a relatively small mass. However, since the surface of a space platform, in contrast to space antennas, is usually plane, all the constituent rods of the construction have an identical length, and in addition, all the junctions of the supporting framework are identical. In short, space platforms can be assembled from standardized elements (like a "space constructor").

Two types of rods and one type of junction are necessary for the assembly of plane space platforms. The rods can be of the most different configuration: prismatic, trihedral (solid or with a latticed surface), cylindrical (also solid and latticed) or conical of two truncated cones (fitting into one another for more compact packing). However, the joining of the rods to the junctions can be accomplished using cylindrical joints, with [illegible], and also with automatically latching connections (for example, ball locks).

Space platforms of any shape and size can be assembled from all these elements. However, as already mentioned, the assembly of constructions of the spatial rod girder type requires a great amount of assembly work with the participation of cosmonaut-assemblers. Robots are now being developed which will be

capable of building up a construction of such a type, but only in one direction (for example, to assemble trihedral or tetrahedral prismatic rods of an arbitrary length). But for the time being there are no engineering solutions making possible the automation of the process of build-up of a construction of such a type in two directions. As a result, the assembly of space platforms will be very time consuming and will necessitate the in-orbit presence of cosmonaut-assemblers for a long time. They will accomplish this assembly either directly or by means of manipulators.

Due to this shortcoming of space platforms, the basis for which is a construction of the spatial rod girder type, an intensive search is now being made for designs of a space platform allowing greater automation during assembly in orbit. For example, it is surmised that the supporting framework of a space platform may constitute a construction with a spiral structure of the crossed beams or crossed girders type, and also a hierarchical construction like that considered above in the description of a possible variant of the supporting framework for solar cells in satellite solar electric power stations.

The assembly of a space platform having a design with a spiral structure can be accomplished by only one automatic apparatus unwinding an aluminum strip (with a width of about 4.5 m) in the form of a spiral and putting in place radial bonds connecting adjacent branches of the spiral. This process is virtually completely automated but such a construction of a space platform has a very low rigidity and the possibility of its real operation is doubtful.

Constructions of the crossed girders type are somewhat more massive than constructions of the spatial rod girder type, but a high percentage of the assembly operations here can be automated. The fact is that all the connections of such girders allow the use of manipulators and as a result the total productivity is greater than in the assembly of constructions of the spatial rod girder type.

In any case, the construction of large-dimensional structures will be accomplished with adequate efficiency only when using different kinds of automatic apparatus for these purposes. The section which follows will tell about their development and how other problems in construction technology are solved when constructing large-dimensional structures in space.

Technological Aspects of Construction in Space

For the modern reader the term "construction" is usually associated with the idea of powerful earth-moving machines, the latticed masts of tower cranes, enormous concrete blocks, and finally, the noise and dust of construction sites. And various types of construction, buildings and structures are naturally seen as an embodiment of something fixed, solidly resting on a strong foundation. Only with some leniency is the term "construction" generalized for the process of building aircraft, ships, locomotives and some other kinds of transport vehicles.

With these prevailing concepts concerning terrestrial construction the technology of construction in space and the operation of different structures at first glance seems simpler. After all, in circumterrestrial orbits there is

no gravity, no wind loads and no atmospheric corrosion. In actuality, however, the situation is far more complex: weightlessness prevails, but there is an intense vacuum and powerful radiation; there are no wind loads but enormous dynamic loads arise on the space vehicle when it is being put into orbit, during its orientation and orbital correction; the earth's atmosphere has virtually no effect, but considerable temperature differentials, etc. are operative.

The unusual conditions in circumterrestrial orbit and in distant space dictate definite requirements on the technology of construction of large-dimensional space structures (this will be discussed in this section) and on the operation of space structures (the next section will be devoted to this subject). However, first we will examine what requirements are imposed on construction materials. It should be noted that technological aspects and operation and choice of construction materials in space construction are closely related to one another and the appearance of new solutions in any of these links immediately is reflected productively in the technical solution in other links and even in the choice of an optimum variant of the type of construction.

Construction materials for space structures. In contrast to stone, concrete and other well-known terrestrial construction materials, in space construction it is for the most part different metallic alloys which are used because these have the necessary strength and rigidity characteristics. The restriction on mass, dictated by the possibilities of rocket-space transport vehicles, results in the broader use of lighter alloys. The alloys used in the aviation industry have come into the widest use. On the one hand, the requirement of a relatively low density of material is important in aviation as well, and on the other hand, the application of the advances in the already quite developed aviation industry is an important factor.

Aluminum alloys are used more frequently than others in space constructions, but in many cases there is recourse to titanium, magnesium and beryllium alloys, steel, etc. All these materials have high strength and rigidity and over the course of the decades can function under space conditions virtually without deterioration of their mechanical properties. However, all these materials are characterized by substantial shortcomings: relatively great density, high coefficient of expansion, low decrement of characteristic oscillations.

It has already been noted that the material of space constructions should retain its performance in a wide range of temperatures, in some cases varying from -150 to +150°C. In order to reduce temperature stresses and strains it is necessary to select a material with a low coefficient of linear expansion and a relatively high thermal conductivity. And since from time to time space constructions are acted upon by considerable dynamic loads, among other qualities the material must also have a high decrement of characteristic oscillations, that is, these oscillations must attenuate rapidly.

Unfortunately, as already noted, the materials used in modern space constructions do not fully meet these requirements; in the best of cases they lack only one of the enumerated shortcomings. Thus, aluminum alloys have a relatively low density, but at the same time they are characterized by a high

coefficient of linear expansion. Invar alloys have a low coefficient of linear expansion but are characterized by a high density and a low decrement of characteristic oscillations, etc.

Fig. 10. Rigidity characteristics of materials used in space constructions.

There is a good possibility for clarifying the existing situation with a changeover to composition materials for the construction of space structures. As a minimum such materials consist of two components: reinforcing fibers (filler) and bonding material (matrix). The fibers provide adequately high strength, rigidity and thermoelastic characteristics for the material as a whole, whereas the matrix, ensuring a fixed position of the fibers and distributing the force among them, also safeguards the fibers from mechanical and chemical damage.

Composition materials based on graphite fibers (so-called carbon plastics) are attracting the greatest attention. In these materials epoxy, polyamide or polysulfone resins are used as the matrix. Such materials have a very high relative strength and rigidity (Fig. 10), a low coefficient of linear expansion*, a high decrement of characteristic oscillations and good fatigue characteristics.

Depending on the type and percentage of reinforcement (that is, the quantity of filler), and also on the type of bonding material the mechanical characteristics of the carbon plastics can change somewhat, but in general, as a rule they are quite high. However, some data indicate that during prolonged exposure in a vacuum under the influence of cosmic radiation the mechanical properties of the carbon plastics begin to deteriorate considerably. Accordingly, in constructions intended for prolonged use in space (for example, the minimum lifetime of satellite solar electric power stations is estimated at 30 years) the outer surfaces of the carbon plastics must be covered with a thin protective layer of metals.

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* Graphite fibers have a negative coefficient of linear expansion, whereas the matrix materials have a positive coefficient of linear expansion. Theoretically with an appropriate choice of fibers and bonding material it is also possible to obtain a zero coefficient of linear expansion. However, in actual practice it is for the time being very difficult to achieve this.

During recent years a technology has been developed for the mixing of graphite fibers with metals; this has made it possible to develop composition materials with metallic matrices. The composition material graphite-magnesium was developed on this basis; it has the highest isotropicity among all the composition materials developed up to the present time.

In large space structures the use of carbon plastics will afford an economy in the mass of supporting structures by 30-50% in comparison with constructions made from aluminum and magnesium alloys. Accordingly, in the immediate future one should expect a substantial increase in the volume of production of composition materials, a considerable reduction of their cost, and also the broader introduction of such materials into terrestrial industry.

The technology of fabrication of a wide variety of profiles from carbon plastics has now been mastered: pipes of circular and rectangular cross section, I- and corner profiles and many others. However, the cost of carbon plastics is still quite high, although more carbon plastics are now used in the manufacture of sports goods than for the needs of cosmonautics. Nevertheless, with a considerable increase in production, which will occur with the introduction of at least a part of the planned and developed space constructions from composition materials into cosmonautics, the cost of carbon plastics will decrease considerably.

Composition materials have also been developed on the basis of other types of fibers, especially on the basis of boron fibers. Epoxy resins or aluminum alloys can be used here as a matrix. Boron-aluminum materials also have a high strength and can be used under space conditions without worsening of mechanical properties and have a high elastic modulus (twice as high as for carbon plastics).

However, other characteristics of boron-aluminum materials are poorer than for carbon plastics. They have a relatively high density (almost twice as high as for carbon plastics) and a greater coefficient of linear expansion (almost an order of magnitude greater than for carbon plastics). The decrement of characteristic oscillations is also less by a factor of 1.5.

Development work is also proceeding on other promising materials, especially for the reflecting surface of automatically deployed space antennas. The structural mass of such antennas is now determined for the most part by the mechanical characteristics of reflecting surface materials since the main stresses in elements of the supporting structure arise due to its dilatation. Mechanical and electrostatic constructions require elastic materials, whereas materials with little dilatation, easily straightened out into a plane without wrinkles and depressions, are more suitable for rotating and inflatable constructions.

Technology of couplings of space structures. In the assembly and erection of large-dimensional space structures the technology of couplings of different elements of these structures is of decisive importance. Here particular attention is being given to the ease of use and reliability of the couplings, naturally dependent on the properties of the material used. However, conditions

in circumterrestrial orbit differ so greatly from those on the earth that it is again necessary to develop the simplest types of connecting elements capable of reducing work expenditures and assembly time under space conditions.

In a general case the connections in space constructions may be separable or inseparable. Taking into account the materials used in space constructions, inseparable connections can be made by means of gluing, soldering or welding. Particular emphasis is on the latter, since gluing, for example, is admissible only for connections not subject to the influence of high temperatures and it can be accomplished only with the careful finishing of the surfaces to be joined.

The most different kinds of welding are being studied at the present time for future work on the assembly of large-dimensional space constructions: cold diffusional-vacuum welding, welding using fusing electrodes, electric contact welding, ultrasonic point welding, welding using a laser or electron beam, etc. In particular, a great volume of work on study of the possibility of welding in space has been carried out at the Electric Welding Institute imeni Ye. O. Paton. This made it possible to develop the self-contained "Vulkan" space apparatus which is capable of accomplishing welding with an electron beam, a plasma arc and a fusing electrode, as well as a highly reliable and highly productive apparatus for the welding of thin-walled elements with an electron beam.

A few words must be said concerning welding in space constructions from composition materials of the boron-aluminum type. Since with strong heating a chemical reaction begins between the boron and aluminum, causing a sharp worsening of the mechanical properties of the material, types of welding leading to strong heating of the joined elements (for example, electric arc welding) are inadmissible here. And in general, the choice of the type of connection (both separable and inseparable) is dependent on the material from which the joined elements are fabricated, on the conditions for the operation of the space structures and on the method adopted for the assembly of large-dimensional structures.

The fact is that with a considerable degree of automation of the construction process in space an important role is played by different kinds of separable connections. These include, in particular, cylindrical joints, turnbuckles, flanged joints, conical and ball fittings, etc. The performance of these connections in open space is dependent to a high degree on the choice of the corresponding lubricants so as to prevent the vacuum diffusional welding occurring with the contact of metal surfaces in a deep vacuum.

It should be noted that all the enumerated types of separable connections are rather simple and reliable, but nevertheless require relatively great work expenditures and prolonged construction work in space. Accordingly, much work is now being done on developing locking connections whose use considerably simplifies and accelerates the construction process in orbit. As a rule these connections have conical catches facilitating the matching of the parts to be joined and latches (of the ball type and having plate springs, etc.), activated with the joining and pressing together of these parts.

Reliable automatically locking connections are also extremely promising for repair-preventive maintenance work in open space. For example, in April 1984 an in-orbit repair of the American satellite "SMM" was made during a regular flight of American astronauts. But first an attempt was made to slow its rotation by means of an adaptation with a locking connection on the end. It is true that imperfections in the design of the connection resulted in failure and the matter was further complicated when the American astronaut decided to stop the rotation of the satellite with his hands (as a result, in addition to rotation about its longitudinal axis, the satellite also acquired rotation about its transverse axis).

Nevertheless, use of reliable automatically locking connections undoubtedly should considerably simplify the operations for assembly and repair in orbit and the carrying out of such operations will not require additional energy expenditures. However, such connections assume decisive importance with automation of the construction process in orbit because without them the automated construction of large-dimensional space structures would be inconceivable.

Construction equipment in orbit. The connection of elements of large-dimensional structures in orbit can be accomplished by the astronauts (directly or using remote manipulators), as well as using automatic apparatus in accordance with a stipulated program. In the assembly of large-dimensional constructions it is of considerable importance whether the cosmonaut without the assistance of auxiliary equipment can move long massive construction components and position them in space with the stipulated accuracy relative to the connection points.

For the first time a relatively large volume of work in orbit was performed by the Soviet cosmonauts V. A. Lyakhov and V. V. Ryumin during assembly of the KRT-10 space radio telescope on the "Salyut-6" station. In late 1983 the same V. A. Lyakhov, but together with A. P. Aleksandrov, performed work for the mounting of additional solar cells on the "Salyut-7" station. And then a completely unprecedented volume of work in open space was performed by the next crew of the "Salyut-7," L. D. Kizim, V. A. Solov'yev and O. Yu. At'kov.

We should note the already mentioned work of American astronauts during repair of the "SMM" satellite. In addition, ground studies have been repeatedly made in the United States in which the possibility has been explored for the assembly of large-dimensional constructions by cosmonauts under weightlessness conditions. Weightlessness was simulated in a water basin during movement of elements of the construction on an air cushion and with suspension of the parts on long fibers.

The experiments carried out on earth and in space up to the present time make it possible to hope that with appropriate training the cosmonauts will be able to assemble quite large-dimensional constructions manually. However, the productivity of assembly work in orbit will be increased considerably with the use of remote-controlled manipulators. The use of television cameras will afford the cosmonaut-operator the possibility for control of the remote manipulator, using an enlarged image of the work object (including an object which is beyond the cosmonaut's direct visibility).

Depending on their purpose, such manipulators may be of different complexity. For example, for performing definite operations of the same type it is sufficient to employ a remote manipulator which is a lever to whose free end a tool is attached. In the case of more complex work it is necessary to have remote manipulators simulating the human hand. This type of remote manipulator consists of arm, elbow and wrist parts and to the latter is attached a tong or replaceable tool. A television camera can also be placed at the end of the remote manipulator; this makes it possible to see the object from a close range. An on-board electronic computer can be used in the control system.

In order to lighten the structure of the remote manipulator proposed for the assembly of large-dimensional space constructions it is proposed that its supporting frame be fabricated from hollow tubes (with the use of composition materials) connected by joints supplied with servodrives. Estimates show that such a remote manipulator with a characteristic mass of about 400 kg is capable of moving loads in orbit with a mass up to 30 tons with a speed 0.6 m/sec.

All remote manipulators developed for construction work in space differ with respect to the mobility of the lever (or arm), the number of levers (or arms) and also in the location of the cosmonaut. The latter may be on either a fixed or on a mobile (for example, rotating) base or on its moving end, being situated on a special platform. In the latter case the control of the remote manipulator is accomplished either directly from this platform or from a control panel situated on the base (in this case the cosmonaut-operator will be on the base and the cosmonaut-assembler will be on the platform).

In the case of large volumes of assembly work it is desirable that the control panel be situated in a pressurized cabin, which should ensure prolonged presence of the cosmonaut-operators in adequately comfortable conditions. Such a cabin is supplied with a life-support system, a system for movement of the cabin, and naturally, control panels. In case of necessity control of several remote manipulators can be accomplished simultaneously, and therefore the cabin with the cosmonaut-operators (in actuality, already a servicing station), the remote manipulators themselves with autonomous control, shall we say, from the end platforms, and also different assembly devices (for example, for attachment of the elements of the constructions during the time of assembly) will be placed on their sort of space platform.

The structure of such space construction platforms will differ, depending on the method for assembly in orbit. In one case the assembly can be carried out, so to speak, "from a single place," whereas the construction to be assembled will move and turn appropriately. In another case the space assembly platform in the course of assembly will move along the large-dimensional construction to be assembled. The first variant is similar to a factory process, whereas the second is similar to the construction of a house or ship.

As a rule the first method is intended for the assembly of one type of construction: in producing, for example, several copies of identical constructions. Its technology is extremely promising for the assembly of relatively small constructions. In particular, there is discussion of a project for such

a construction platform for the assembly of a 100-m dish for a space platform. In this project an important element is a rotating "work table" (on which assembly occurs), capable of moving relative to the servicing station.

The assembly of very big large-dimensional constructions of the type of elements of satellite solar electric power stations will evidently require a second assembly method, that is, with movement of the space construction platform along the construction to be assembled. Such platforms measuring 100 x 50 m with a height of about 5 m are now being considered; these will carry the servicing station, several remote manipulators capable of accomplishing assembly under an autonomous program using an electronic computer, different assembly devices and also automatic apparatus of the girder assembler type.

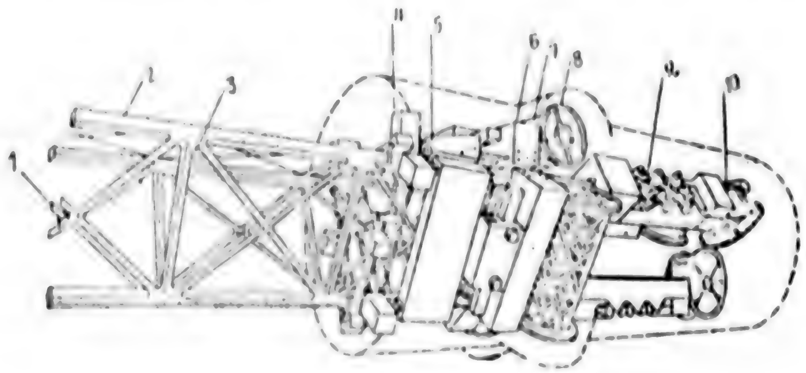

Fig. 11. Diagram of automatic apparatus for producing trihedral girders: 1) girder, 2) side member, 3) lattice, 4) place for ultrasonic welding, 5) cooling chamber, 6) apparatus for forming lattice, 7) heater, 8) spool on which all lattice elements are wound, 9) rollers for shaping side members, 10) spool with wound side member.

A construction platform of this type must without fail be supplied with means for autonomous movement in space and for fixation in stipulated positions. Such a platform will be used both for producing supporting components and for the mounting of functional and auxiliary equipment, tests, repairs, storage of tools, extra equipment and materials. In particular, it can have a cavity in which the assembly takes place and for the testing of fragments of the construction, operation of the solar cells, etc.

Use of automatic apparatus in space construction. The efficiency of operation of the considered space construction platforms will be determined to a great extent by the degree of introduction of automatic apparatus into construction work, that i., the automation of the entire construction process and the use of automatic apparatus for the assembly of constructions. Even the productivity of operation of remote manipulators is relatively low if a great amount of assembly work is performed without automation of at least a part of the operations performed.

Automatic apparatus capable of fabricating in orbit girders used as rod elements for large-dimensional space constructions from semifinished materials delivered from earth are now fully developed. These can shape girders of a circular cross section in orbit from wound rod blanks, as well as girders with the cross section of an equilateral triangle from rolled sheet material and transverse elements stamped on earth.

An experimental model of an apparatus for the automatic and continuous fabrication of trihedral girders from rolled material of the carbon plastic type, for example, has been developed and tested on earth (Fig. 11). The girder which it produces consists of three longitudinal elements (side members) situated at the vertices of a triangular cross section, connected to one another by transverse elements (lattice). In this case strips of sheet material will be produced on earth and wound onto the spools of the girder assembler in such a quantity that in orbit it will be able to produce girders with a total length from 0.5 to 1 km. The possibility of delivery of additional spools for the girder assembler is visualized, as well as the reloading of spools under space conditions.

In the course of operation of the girder assembler the strips from which the side members are fabricated are unwound from the spools and pass through a heater, from whence, after becoming more flexible, they are fed to rollers which shape a triangular section from the flat strip. Thereafter the side elements are fed to a cooling chamber where they harden and upon emerging from there the lattice elements are joined to them.

This latticework is fabricated on the earth from flat strip, cut in a stipulated form, and also wound onto spools. The lattice material fed to the girder assembler, unwinding from three spools, again passes through a heater and after its passage a mechanism of the press type shapes the transverse sections. Then the lattice material, naturally, is cooled and joined to the side members by means of ultrasonic welding.

In the fabrication of the girders it is necessary to adhere to the rate of movement of the strips in order to avoid curvature of the axis of the girder and bending of the side members. In order to monitor this rate provision is made for an automatic system with a feedback, which includes corresponding sensors, servomechanisms and electronic devices. The on-board computer exercises general control and coordination.

A similiar automatic girder assembler has been developed for the fabrication of trihedral girders from aluminum strip. There is some difference here in the change in the temperature regime and the replacement of ultrasonic welding by point welding. Automatic apparatus has also been planned which uses a somewhat different technology: in this apparatus the side members are connected by diagonals and struts delivered from the earth.

An apparatus for automatic in-orbit fabrication of cylindrical lattice elements (geodesic beams) has good indices. It can produce geodesic beams with linear and curvilinear axes from carbon plastic rods delivered from earth

and also join the end elements necessary for the assembly of large-dimensional constructions from geodesic beams on the earth.

The completely loaded automatic apparatus (Fig. 12) will produce 200 geodesic beams with a length of 130 m and a diameter of 1.7 m in orbit. Each of them will be able to withstand axial loads up to 4500 N.

With a characteristic mass of about 4 tons, such an automatic apparatus can be loaded with assembly elements with a mass up to 20 tons. The power consumption on assembly is relatively small since the power for the most part is necessary for the joining of the rods at the junctions by means of ultrasonic welding and for their cutting. It should be noted that as elements of large-dimensional constructions geodesic beams, receiving only compressive forces, are 20-40% more economical in mass than trihedral girders.

In the more remote future the automatic girder assemblers examined here will form part of more complex automatic assembly apparatuses intended for the assembly of large-dimensional constructions of elements of the same type. A study was made of the possibility of constructing automatic apparatuses which from rolled semifinished materials could immediately produce a large-dimensional construction of plane or cup-shaped configuration in space. However, at the present time the development of such automatic apparatus is only in the very preliminary stage of study and is meeting with a number of difficulties.

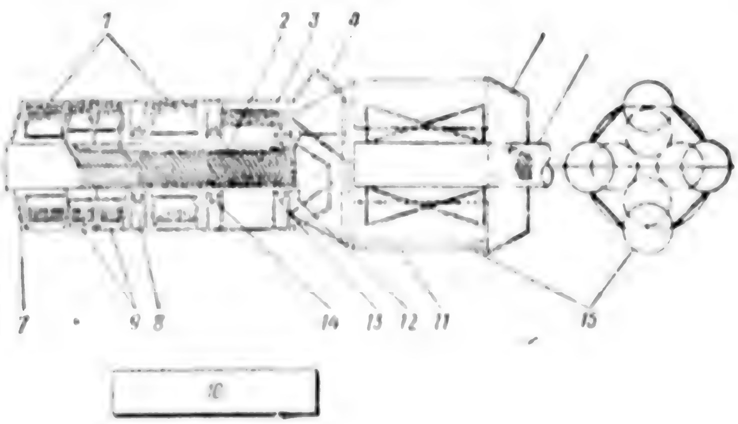

Fig. 12. Automatic apparatus for fabrication of geodesic beams.

KEY:

1. Container for oblique elements
2. Conveyer
3. Storage for annular elements
4, 5. Remote manipulators
6. Finished geodesic beams
7. Mandrel
8. System for joining longitudinal and oblique elements
9. Container for longitudinal elements
11. Pressure collar
12. Shears
13, 14. System for joining longitudinal and oblique elements
15. Finished elements.

Operational Requirements

Weightlessness makes it possible to deploy extremely openwork structures in space even impossible on the earth. Nevertheless, all space structures are acted upon by diverse forces which must be taken into account in developing space apparatus, especially if these have very great dimensions. External forces usually cause movement of the center of gravity (mass) of the construction or give rise to a rotational moment, whereas internal forces lead only to its deformation.

Allowance for external forces. These are frequently neglected when developing small space constructions because the external loads are relatively small. The most significant of these arise during the transport of constructions. In a general case, even in the absence of restrictions imposed by the mass and size capabilities of rocket-space transport vehicles, it is feasible to carry out the assembly of space structures directly in working orbit or a somewhat lower orbit. However, great accelerations during the transport of an assembled structure from a lower orbit into a higher orbit (such as a geostationary orbit) can be avoided if low-thrust engines are used for this purpose.

These include, for example, electrojet engines, which, incidentally, are more economical than liquid-fuel rocket engines usually employed with carrier-rockets. However, the accelerations generated by such engines nevertheless cannot be very small (if for no other reason than that the transport time must not be very great); in the best variant the inertial forces operative on the structure constitute 0.1% of the gravity on the earth.

Tidal forces also become substantial for large-dimensional space structures. The fact is that satellites revolving around the earth are acted upon by oppositely directed forces of terrestrial attraction and centifugal force which are in equilibrium at the center of mass (and hence weightlessness develops). However, the first decreases with distance from the earth, whereas the other, on the contrary, increases (although to a lesser degree), which leads to an inequality of these forces in the parts of the construction more remote from the earth and closer to it. This gives rise to tidal forces dilatating the space structure in opposite directions along the axis passing through the center of the earth and the center of mass of the space structure.

Nevertheless, deformation due to tidal forces is negligible even for more or less large-dimensional constructions if they are in a sufficiently high orbit. After all, with an increase in distance from the earth the difference in terrestrial attraction of different parts of the construction becomes less. And in any case this tidal effect exerts almost no influence on spherical constructions measuring up to 10 km. But with transition to the specific space constructions which were examined in the preceding sections an allowance for the tidal effect is nevertheless necessary and here is why.

If the orientation of such constructions was without importance, everything would be in order. But the fact is that for space antennas, the elements of satellite solar electric power stations and even space platforms orientation at the time of their functioning is of considerable importance. Here also

the tidal forces generate a rotational moment (in the scientific literature this is frequently called the gravitational moment) for nonspherically-symmetric large-dimensional constructions. As a result, oscillations of the structure arise even with adherence to the necessary orientation with the stipulated accuracy.

For example, with orientation of a construction in the form of a flat disk with a diameter of 4 km with an accuracy to 1" the frequency of these oscillations attains 0.1 Hz in the case of presence of the space apparatus in low circumterrestrial orbits and 0.0066 Hz when present in a geostationary orbit. Accordingly, for the purpose of preventing resonance phenomena the characteristic frequency of oscillations of planned space constructions must be substantially greater than these values. An increase in the frequency of the characteristic oscillations is possible only by an increase in the rigidity of the construction. Here also the use of materials with better rigidity characteristics and a higher decrement of characteristic oscillations is of assistance.

Among the external loads exerting an appreciable influence on large-dimensional space constructions we must include aerodynamic drag and the pressure of solar radiation. We immediately note the different character of the effect of these forces: aerodynamic drag is always directed toward the motion of the space apparatus in orbit and as a result leads to a lowering of this orbit, whereas the pressure of solar radiation brakes the satellite in one-half of its orbit and accelerates it in the other half. As a result of the latter a change in the velocity of motion of symmetric constructions due to the pressure of solar radiation in the last analysis is negligible.

As indicated by computations, due to a marked decrease in the density of the earth's atmosphere with altitude the aerodynamic drag can also be neglected if the orbital altitude of the satellite exceeds 550 km. However, from the point of view of mass and size capabilities of rocket-space transport craft it is more economical to assemble large-dimensional constructions in orbits with an altitude of 300-500 km. True, with relatively small ratios of the mass of the construction to surface area (for example, area of dish deployment for space antennas) assembly in orbits with an altitude of more than 550 km becomes feasible.

Thus, in a general case with the transport of a large-dimensional space construction from a lower orbit into a higher orbit this construction is subjected to the effect of inertial forces, aerodynamic drag and light pressure, on the one hand, and the thrust of the engines on the other. However, since these forces are imparted to different points of the space construction (Fig. 13), a moment of force arises which bends the structure. In addition, the firing of the engines or a change in their thrust leads to mechanical oscillations of the structure, the nature of which was discussed earlier.

All this is extremely important for gigantic radio and optical telescopes of the mirror type. Accordingly, in their designing it is necessary to take into account the possible deformation of the mirror profile during transport of the mirror from a lower orbit into a higher orbit and also oscillations of

the construction arising at this time. Accordingly, this imposes additional requirements on the elastic properties of the construction, on the one hand, and rigidity characteristics, on the other.

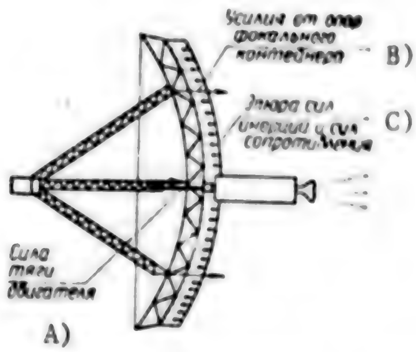

Fig. 13. Diagram of forces acting on framework of space antenna during its transport from lower orbit to higher orbit.

KEY:

A. Engine thrust force
B. Forces from supports of focal container
C. Curve of forces of inertia and drag forces

Among the remaining external effects on a space structure we can mention the influence of the earth's magnetic field. As a result of its nonuniformity eddy currents arise in the components of the space structure having conductivity to one degree or another. The eddy currents cause heating (due to ohmic losses) of such components and a decrease in the kinetic energy of the space structure, which causes its braking and a lowering of orbital altitude. However, this braking force, forming as a result of nonuniformity of the earth's magnetic field, is negligible for most large-dimensional space constructions.

But since the effect of the magnetic field increases substantially for rotating conducting bodies, the earth's magnetic field cannot be neglected in centrifugal space constructions, and also for satellites stabilized by rotation. True, allowance for the developing braking forces does not pertain to the strength characteristics of the structure, but only expenditures of its mass and energy on stabilization of the velocity of rotation. However, the development of virtually nonconducting composition materials can be of assistance here since the space structures of the considered type fabricated from them will not be subjected at all to the influence of magnetic field nonuniformity.

Allowance for internal loads. In addition to external forces, space structures are acted upon by a variety of internal loads (temperature stresses, internal pressure, internal centrifugal forces, loads associated with the movement of mass along the surface and through the volume of the structure, etc.), which in some cases are decisive in the choice of materials, type of construction and technology for the assembly of space structures.

Thus, for example, with rotation of the structure relative to its center of mass centrifugal forces arise in it. And precisely this relates to the cases just examined, when stabilization of the space apparatus can be brought about due to the gyroscopic effect during the time of rotation or, in general, when the type of construction is determined by centrifugal forces. The stresses and strains forming in the structures in all these cases must not exceed the corresponding tensile strength of the material used.

In addition, a rotational moment arises in any space structure during its orientation or stabilization relative to a stipulated direction. True, it must be noted that with precise orientation with admissible frequencies of mechanical oscillations the limitation imposed by the considered operation of centrifugal forces begins to be expressed only for large-dimensional space structures with a dimension of several hundreds of kilometers.

The influence of centrifugal forces is also important for future space constructions with artificial gravity created at their periphery due to rotation of the structure. Such structures must have considerable dimensions both because of their purpose and because in the case of small dimensions the creation of artificial gravity due to rotation results in the formation of Coriolis accelerations which are extremely painful for cosmonauts. However, computations show that the stresses and strains in such structures, arising as a result of the operation of centrifugal forces, limit the dimensions of these space settlements to a maximum of 2 km (true, there are projects for inhabited structures of a greater size, but the artificial gravity for them would be created in a central block measuring from 0.5 to 2 km).

Now we will examine the temperature stresses always characteristic of space structures since they, not even having their own sources of heat, are subject to nonuniform heating by the sun. To be sure, if the orientation of the space apparatuses did not change relative to the sun the temperature deformations could be compensated for in advance by structural innovations. But, as a rule (with the exception of solar cells), space structures rotate relative to the direction toward the sun and as a result a wave of temperature deformations is formed.

In principle, the evening-out of temperature in a space structure is possible by pumping through a heat-transfer agent or the applying of heat insulation, but for large-dimensional space structures this method is infeasible. It is true that even a number of large-dimensional constructions (such as centrifugal) are little affected by temperature deformations. The fact is that during rapid rotation the amplitude of the wave of temperature deformations is insignificant.

However, for most slowly rotating large-dimensional structures nonuniform heating by the sun is a serious problem. There are several ways to contend with this and the simplest of these is a decrease in the mean equilibrium temperature of the space apparatus, which is possible, for example, by the radiation of the excess heat into space. In such a case, by an appropriate choice of coverings, it is possible, in a wide range, to regulate the relationship between the emissivity and absorptivity of space apparatus surfaces.

For example, the use of dielectric coatings (titanium dioxide, silicon oxide, titanorutile dioxide, etc.) makes it possible to reduce the mean equilibrium temperature of space constructions to -15-0°C.

Still another and even more effective method for lessening temperature deformations is the use of materials with a small coefficient of linear expansion, as was mentioned above. There are also other means for the thermal protection of space vehicles which have already been described repeatedly on the pages of the brochures in this series (for example, see: G. M. Salakhutdinov, TEPLOVAYA ZASHCHITA V KOSMICHESKOY TEKHNIKE (Thermal Protection in Space Technology), Moscow, 1982).

In addition to temperature loads, the sun exerts a serious effect on space vehicles, being a powerful source of radiation: short-wave radiation (primarily ultraviolet) and corpuscular streams, whose intensity in orbit is much greater than at the earth's surface. In addition, corpuscular streams are generated by cosmic rays and the earth's radiation belts. Streams of corpuscular radiation increase particularly strongly during the time of solar flares, which are also accompanied by a marked intensification of short-wave electromagnetic radiation.

Radiation surfaces, optical parts, semiconductors and the photocells on the solar panels are the most sensitive to short-wave radiation and corpuscular streams. The absorptivity of some coverings is increased, in some cases increasing by a factor of 2-3, which results in serious impairments of the thermal regime. Ceramic coverings are most stable in this case. Under the influence of irradiation there is an impairment of transparency of the glass in ports and optical instruments. However, the latter can be substantially decreased with the addition of cerium oxide to the glass, as well as by using quartz glasses with a low content of impurities.

Corpuscular radiation causes radiation damage to materials of different kinds, but we will not discuss this here because it is beyond the scope of our subject.

Effect of a space vacuum. A space vacuum imposes increased demands on construction materials. This applies, in particular, to manned stations, pressurized instrument compartments and inflatable structures. In living spaces an internal pressure must be maintained which is close to atmospheric pressure. Considerations of strength dictate that for a particular pressure the wall thickness of a living space must increase proportionally to its volume. Accordingly, for very large space structures it may become completely impossible. For this reason the possibility of establishing large settlements will be determined to a considerable degree by progress in the field of development of materials with adequate strength characteristics.

The need for maintaining a constant pressure in a manned construction complex increases the danger of penetration of meteoroids. It is true that the probability of penetration of a meteoroid with a mass of several tens of grams, which can considerably damage a construction of the [illegible] type, is so small that it can be neglected. However, a chance collision with a meteoroid is capable of causing only some small damage which would not give a

significant effect on its operability, a through penetration of the wall of a pressurized compartment would cause leakage of the atmosphere and result in serious damage.

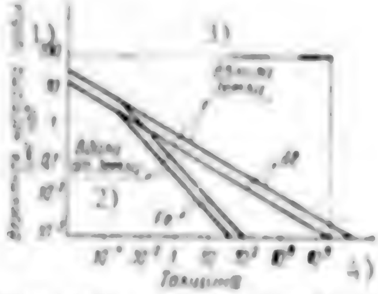

Fig. 14. Dependence of probability of penetration of aluminum and iron walls of space vehicles by micrometeoroids on wall thickness.

KEY:

1. Probable frequency of penetration, $1/m^2 \cdot$year
2. Distant from earth
3. Near earth
4. Thickness

The effect of meteoroids is dependent on their velocity and mass. For example, the collision of particles with a mass of 10^{-7} g with a space vehicle leads only to erosion of the surface of the vehicle and computations show that the total loss of matter as a result of such erosion near the earth does not exceed several fractions of a micrometer per year and this cannot exert a significant effect on the strength of the space structure. However, due to erosion there will be a change in the characteristics of the windows, lenses, heat-protective coverings and reflecting surfaces. Accordingly, for maintaining the prolonged functioning of the heat-protective coverings and reflecting surfaces it will be necessary to renew them periodically.

Meteoroids with a mass of more than 10^{-7} g can cause the depressurization of thin-walled space structures (Fig. 14). The simplest method for protection against this is the use of double-walled structures. The outer thin wall for them serves for the fragmentation of meteoroids into fine fragments, and the inner wall is for pressurization. The gap between the walls is determined from the condition of adequately broad scatter of fragments. Such a system makes it possible to reduce the mass of pressurized structures by almost an order of magnitude.

In a space vacuum the sublimation and evaporation of matter are considerably facilitated, but usually at a temperature of less than 150° the materials of space structures lose little matter as a result of this. However, the use of alloys (such as zinc or magnesium), having easily evaporating components, is inadmissible in space construction without taking special measures for their protection. For example, the sublimation of metals can be reduced considerably by applying protective coatings (oxide, phosphate) to the surface. These have a greater stability in a vacuum than the basic metals. However, the space vacuum exerts no substantial influence on the mechanical properties of metals.

As already noted, a special problem is the performance of friction surfaces of space constructions under the conditions of a deep vacuum. With prolonged presence in a space vacuum the surface of metals loses the adsorbed gases and oxide films, which under terrestrial conditions play the role of a lubricant. And as a result of the high degree of purity of the surfaces of space constructions an unforeseen diffusional welding of the frictional parts can arise. A number of methods have been proposed for eliminating this harmful influence of a space vacuum. These are based both on design decisions and on the use of hard coverings with a low friction coefficient (for example, molybdenum disilicide or fluid lubricants with a low vapor pressure).

Space Structures Beyond Limits of Circumterrestrial Orbit

In this brochure we have examined different aspects of construction of large-dimensional structures intended for use in circumterrestrial orbits in long-range programs for the mastery of space. The construction of large-dimensional structures of the type of a scientific base or production complexes (both manned and automated) on the moon, planets and other bodies of the solar system will require completely different design and construction decisions. The same applies to space settlements of the more remote future, like the "space cities" visualized by Tsiolkovskiy and colonies of earthlings on other celestial bodies.

Among the different bodies of the solar system it is naturally the moon which attracts the greatest attention. And it is not just because it is closer to us than other bodies. The absence of an atmosphere, so interfering with surface scientific research and impeding the productive use of the entire range for radio communication, an insignificant gravity, 6 times less than at the earth's surface, favoring the construction of relatively massive structures, the constant turning of only one side toward the earth, favoring the maintenance of constant or emergency communication, and many, many other factors explain precisely why the moon is the most attractive place for establishing the first scientific-production bases.

The use of the raw material resources of the moon will be of great importance for the further development of cosmonautics, both for local needs (for example, the construction of lunar bases) and for building of space structures in circumterrestrial orbits (for example, in the construction of satellite solar electric power stations). Several methods for the inexpensive transport of freight from the moon into circumterrestrial orbit have already been proposed. Usually it is assumed that there will be a preliminary accumulation of transportable freight at the libration points of the lunar orbit using automatic apparatus ("catchers"), which then will begin to "ferry" the mass of freight accumulating there to the earth.

Evidently the first experimental scientific base on the moon will begin to function already at the beginning of the next century, long prior to the appearance in circumterrestrial orbit of the first satellite solar electric power stations, the construction of which will require the broadest international cooperation. In the preliminary stage specialized stations will be launched into circumlunar orbit for the purpose of global study of the lunar surface and the choice of the most favorable site for a lunar base. As time passes, after preliminary work on the production and processing of lunar

resources and after adequate automation of production work, it will be feasible to construct a lunar living complex of 10-12 men for general monitoring and control of the automated process. In addition, scientific research will be carried out, using, for example, gigantic radio antennas constructed by this time on the lunar surface.

In their layout the first lunar settlements should be relatively simple and may consist, for example, of the compartments of space vehicles strewn with lunar ground for the shielding of personnel against radiation. For this purpose it is necessary to solve a number of important problems, in particular, related to the supplying of lunar bases with the necessary energy. The fact is that during the period of the lunar night, lasting about 14 earth days, the various assemblies on its surface will be deprived of sunlight, such a natural source of energy widely used in modern cosmonautics. Evidently, here, in addition to the alternative power sources, use will be made of space solar electric power stations like the already examined satellite solar electric power stations, but situated at the libration points of the lunar orbit.

The most fundamental difference between all space living and production structures from similar structures on the earth is the requirement that they be absolutely airtight. Accordingly, the traditional construction materials used on the earth, brick and concrete, are completely unusable either on the moon or even on Mars (its atmosphere is nevertheless very rarefied) or on the other planets, as, however, is the case in open space. It is true that some rooms (such as warehouse space) can also be constructed of the materials employed in terrestrial construction, since work in spacesuits is admissible in them. Both on the moon and on Mars the walls and roofs of these rooms require less construction material due to lessened gravity.

Since all such space settlements will be pressurized from within, due to the requirement of maximum strength with a minimum of mass the walls of the structures should have a complex configuration. As a result, for the moon and planets the most acceptable configuration of the space structures on their surfaces will be a dome. All the exits from settlements on the moon and planets should naturally be supplied with transfer chambers. However, since with an increase in the size of the space structures there is an increase in the probability of their penetration by meteoroids, in order to avoid depressurization of the entire structure it will evidently be divided into individually pressurized compartments, the same as is done in surface vessels and submarines.

The methods for stabilizing the temperature regime of inhabited rooms may differ completely from those on the earth. After all, in space, as already noted, heat exchange with the outside is possible only by means of radiation. Therefore, the color of walls of buildings on the moon and planets will be determined primarily by the stipulated temperature regime. On the moon, for example, it would be desirable that the color of structures changed in relationship to solar altitude.

Naturally, construction on the moon and planets will become possible only with an adequate degree of automation of the construction process. Here also there is a need for completely new design solut' ns, completely different from those used in construction in circumterrestrial orbits. However, at present there is not even an acceptable approach to these solutions.

It must be said that at the present time for the time being there is not even a unanimous point of view concerning the stages which will occur in the populating of space. In the opinion of some specialists, the first major extraterrestrial cities will appear on the moon; others, however, assume that it is more feasible to establish the first space settlements at the lunar libration points. There are proposals that the asteroids be settled first. But in any case many scientists foresee settlement of the planets at a far later stage. Here also there is no unanimous point of view and some even assume that it is more feasible to colonize the neighborhood of Jupiter and Saturn, and not, for example, Mars.

However, the most remote prospects for settlement of the solar system are related to projects of the "cities in the ether" type, that is, settlements located directly in open space. The construction of these gigantic settlements in all probability will be a continuous process and should continue right up to exhaustion of all the resources in the solar system. However strange it may be, even now there are several proposals for space settlements for such a distant future. Even from the times of K. E. Tsiolkovskiy they have been thoroughly discussed in both the scientific and in the popular science literature. Apparently the reader is quite familiar with them, and if not, he can consult the quite extensive literature on this subject (for example, see A. T. Ulubekov, BOGATSTVA VNEZEMNYKH RESURSOV (Wealth of Extraterrestrial Resources), Moscow, 1984).

And nevertheless, in ending our brochure we note that space construction is a completely new direction in cosmonautics whose development will require both careful methodological research and bold engineering imagination. And without question the space construction industry will play a more and more important role in the life of mankind, which is related to man's unending striving to transform nature for his practical needs.

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5303
CSO: 1866/8

COSMONAUTS REPORT ON SPACE WELDING AT CONFERENCE

Kiev RABOCHAYA GAZETA in Russian 19 Oct 84 p 3

[Excerpt] Kiev, 18 October--Today, Vladimir Dzhanibekov, commander of the crew of an expedition that visited the orbiting scientific research complex, and Svetlana Savitskaya, flight engineer of this crew, reported to scientists here on results of tests in space of the multipurpose hand welding tool "URI" in July of this year. This tool was developed at the Ukrainian Academy of Sciences' Institute of Electric Welding imeni Paton.

S. Ye. Savitskaya and V. A. Dzhanibekov gave a detailed account of this experiment at a plenary meeting of the Joint Session of the Scientific Council on the Problem "New Welling Processes and Welded Structures" of the USSR State Committee for Science and Technology, and the Coordinating Council on Welding of the electric welding institute. Academician B. Ye. Paton presided over this meeting.

The participants in the plenary meeting also heard a report by Academician G. A. Nikolayev, president of the Moscow Higher Technical School imeni Bauman, on welding in construction in conditions of accelerated scientific and technical progress; and a report by D. A. Dudko, member of the Ukrainian Academy of Sciences, on the advancement of work on protective and wear-resistant coatings. A report by I. K. Pokhodin, member of the Ukrainian academy, was devoted to the development of production of welding materials in the USSR and ways of heightening the quality of these materials. The quality of Soviet welding equipment for automated processes and trends of their development were the topic of a report by V. V. Smirnov, director of the Ministry of the Electrical Equipment Industry's All-Union Scientific Research Institute of Electric Welding Equipment.

FTD/SNAP
CSO: 1866/67

PATON COMMENTS ON RESULTS OF SPACE WELDING TESTS

Moscow PRAVDA in Russian 5 Nov 84 p 3

[Article by O. Gusev, correspondent (Kiev)]

[Abstract] The article reports on assessments that were made of the space welding tool developed by the Institute of Electric Welding imeni Paton at a recent meeting of the institute's scientific coordinating council. Cosmonauts Vladimir Dzhanibekov and Svetlana Savitskaya reported at the meeting on their work with the multipurpose hand welding tool during their mission on the "Salyut-7" space station.

The following comments by Academician B. Ye. Paton regarding the experiment in space are quoted in the article: "Studying its results, one must not disregard the anxiety of persons who were working in open space, and the setting, which was entirely different from that of an earth pressure chamber, as well as the very fact that such welding was being performed in orbit for the first time. Therefore one must give a very high appraisal of the specimens of metal joined by the method of hand electron-beam welding in space, despite the fact that certain defects are present. There is no doubt that in upcoming missions, it will be possible to begin performing practical work using this method.

"It is not a simple matter to burn through a thin sheet of metal in zero gravity. In these conditions, the cutting of plates requires good focusing of the electron beam, steady movement of the tool, and in some cases returning to sectors that have been cut poorly. It is encouraging that the cosmonauts handled the cutting of metal well. The soldering process proved to be more complex. But even here the cosmonauts managed to obtain several good specimens. The spraying of coatings did not present special difficulties for the cosmonauts, and the specimens obtained in orbit, at least externally, can satisfy the requirements of the most rigid standards."

FTD/SNAP
CSO: 1866/67

CZECH INSTITUTE DEVELOPS MICROCOMPUTER FOR SATELLITES

Moscow MOSKOVSKAYA PRAVDA in Russian 17 Oct 84 p 4

[Text] Scientists and specialists of the Prague Institute of Physics of the Czechoslovak Academy of Sciences have fulfilled an important assignment. At the direction of the "Intercosmos" council on international cooperation in the field of the study and use of outer space, they designed a microcomputer which ensures control of scientific programs on board artificial Earth satellites. The miniature computer will be sent into space next year.

Within the framework of the "Intercosmos" system, specialists of many scientific research institutes of the Czechoslovak Socialist Republic are taking an active part in the implementation of a very full program for the study of outer space. They are working on the development of a new generation of small artificial Earth satellites, and taking part in the preparation and conduct of space experiments. Instruments and apparatus manufactured by leading enterprises of the republic are being used for research in the fields of space physics, medicine and meteorology.

FTD/SNAP
CSO: 1866/67

DEVELOPMENT OF TV SYSTEMS FOR SPACECRAFT

Moscow IZVESTIYA in Russian 25 Oct 84 p 3

[Article by V. Krichevskiy, engineer]

[Abstract] The author recalls landmarks in the development of television systems for spacecraft, beginning with the system that was developed for photographing the back side of the moon from the unmanned station "Luna-3" in 1959. He mentions that the development of that system was assigned to a group headed by Doctor of Technical Sciences Igor' Aleksandrovich Rosselevich, who is said to have directed work on practically all TV systems for the Soviet space program. Among the most recent accomplishments in this area, the author notes that during the mission of cosmonauts L. Kizim, V. Solov'yev and O. At'kov, TV information was transmitted from the "Soyuz-T" spaceship to the "Salyut-7" station for the first time, and materials of echolocation studies of the heart were transmitted via TV channels from the orbiting complex. The author also notes the great importance of space TV systems for observing meteorological processes and for studying Earth natural resources, and mentions that work in this area has been directed by Adronik Gevondovich Iosif'yan, member of the Armenian Academy of Sciences.

In conclusion, the author praises the work of mechanics and assemblers involved with the space TV systems. He names V. Klapovskiy, P. Yanyushkin, N. Strakhov, V. Kovyar and V. Bort.

FTD/SNAP
CSO: 1866/67

OPTICS INSTITUTE'S DEVELOPMENT OF EQUIPMENT FOR COMET PROBE

Leningrad LENINGRADSKAYA PRAVDA in Russian 16 Dec 84 p 3

[Article by N. Orlov]

[Abstract] The article reports on the work of scientists who developed unique optical components for the international probes of Halley's Comet. The career of Doctor of Technical Sciences, Professor Mikhail Mikhaylovich Rusinov, a laureate of the Lenin and USSR State Prizes, is briefly traced in this connection. The chair of instruction which Rusinov heads at the Leningrad Institute of Precision Mechanics and Optics (LITMO) reportedly was the chief organization in charge of developing some of the spacecraft's optical equipment and did most of the research connected with this project. Personnel of several other LITMO chairs of instruction, a design and experimental bureau and a test-and-experimental plant also took part in the project.

Rusinov and his colleagues developed the complex optical components of the television system which will be used for observations of Halley's Comet and for controlling the spacecraft's rotating platform and aiming scientific instruments at the comet. Installed on this platform are television cameras developed at LITMO and in France. The Soviet optical equipment was built on a titanium base and the French equipment on a glass base, according to Rusinov. The television system reportedly employs lenses of the "Russar" type. One such lens, the "Russar-80," was developed by the LITMO scientists in collaboration with the optics laboratory of the Central Scientific Research Institute of Geodesy, Aerial Photography and Cartography imeni Krasovskiy in Leningrad. It is mentioned that this lens belongs to the fifth generation of "Russar" lenses, and that the scientists are working on a sixth generation. Lenses of this series reportedly have found use in a number of areas. Sea currents of the Northern Sea Route and coastal-shelf outlines have been determined and high-speed processes in nuclear physics have been recorded with the aid of "Russar" lenses, for example, and they are used in optical-fiber instruments.

Rusinov praised the work of colleagues who took part in the project, particularly candidates of technical sciences Azim Shakhverdovich Shakhverdov and Nadezhda Alekseyevna Agal'tsova, associates of an optics laboratory; Candidate of Technical Sciences Galina Ivanovna Tsukanova, a docent of LITMO;

and Dmitriy Mikhaylovich Rumyantsev, head of a design bureau. Tsukanova and Rumyantsev directed work on development of the television lenses that are installed in the spacecraft instruments.

(A photograph is given showing M. M. Rusinov, N. A. Agal'tsova and A. Sh. Shakhverdov with a large number of lenses of various sizes.)

FTD/SNAP
CSO: 1866/67

UDC 629.787

MATHEMATICAL MODEL FOR ROLLOUT OF PLANET ROVING VEHICLE FROM LANDING CRAFT

Moscow KOSMICHESKIYE ISSLEDOVANIYA in Russian Vol 22, No 4, Jul-Aug 84 (manuscript received 12 May 83) pp 543-556

GRIGOR'YEV, Ye. I. and YERMAKOV, S. N.

[Abstract] A planet roving vehicle rolls down a landing ramp from the descent vehicle onto a planet surface. The motion of the planet rover during rollout is described mathematically, with the following assumptions: The rover consists of an absolutely solid frame, motor and wheels which have inertial mass and are coupled by individual torsional suspensions with longitudinal rocking of the support arms. Each wheel is elastically deformable in three mutually perpendicular directions at the point of contact. The elements of the disembarkation platform ramp are absolutely rigid and the planet's soil is elasto-plastic. The analysis specifies the conditions for the contact of the wheels and the planet surface. The purely theoretical analysis provides equations for the kinetics of vehicle motion during rollout. Figures 5; references 6: 5 Russian, 1 Western.
[2-8225]

UDC 629.78.015.001

SELECTION OF OPTIMAL CONTROL PROGRAM FOR SOLAR CELL PANELS OF EARTH SATELLITES

Moscow KOSMICHESKIYE ISSLEDOVANIYA in Russian Vol 22, No 1, Jan-Feb 84 (manuscript received 9 Jun 80) pp 44-52

OGARKOV, V. I.

[Abstract] The power available from the solar panels of an earth satellite is proportional to the cosine of the angle a between the line to the sun and the normal to the panel surface. This paper treats cos(a) as an optimizable parameter in deriving an optimal control routine for solar panels that assures a maximum of specified energy output. Simpler expressions than those found in earlier literature are obtained for cos(a) which significantly simplify the analysis of the optimal programs. Two control programs

are analyzed: 1) a program that provides for a maximum of cos(a) with a continuous control function; 2) one which maximizes cos(a), but with a discrete control function. The case in which a specified value of cos(a) is to be achieved with additional constraints (minimization of aerodynamic forces or moments on the satellite) is also analyzed. Analytical expressions are derived for the minimization of the total mass of the solar cells and storage batteries which assure a specific energy capacity. The above analyses are valid for orbits with eccentricities of from 0 to 0.5 and when the angle between the line to the sun and the orbital plane is from 0 to 90°. Since the calculations show that the relative error in computing cos(a) is no more than 0.1 to 0.25%, the proposed analytical expressions may be used not only in the design work, but also in flight control software. The author is grateful to N. I. Stepanov for the fruitful discussion of the results and L. I. Isayeva for formatting the paper. Figures 1; references: 7 Russian.
[125-8225]

SPACE APPLICATIONS

INTERNATIONAL CONFERENCE ON 'COSPAS-SARSAT' SYSTEM

Moscow VOZDUSHNYY TRANSPORT in Russian 1 Nov 84 p 4

[Article by Mikhail Chernyshov]

[Abstract] The article summarizes proceedings of the seventh international conference on rescue satellites of the COSPAS-SARSAT system. The conference was held in Leningrad from 1 to 5 October. Taking part in it were delegates from the system's four founding countries--the USSR, the United States, Canada and France--and from Norway, Great Britain, Bulgaria and Finland, which have joined the system since the beginning of its experimental operation. Denmark and a number of international organizations were also represented at the conference.

A number of participants in the conference are quoted in regard to the COSPAS-SARSAT system's performance to date and its current equipment and facilities. They are said to include three Soviet satellites, "COSPAS-1" ("Cosmos-1383"), "COSPAS-2" ("Cosmos-1447") and "COSPAS-3" ("Cosmos-1574"), and three Soviet ground information-receiving stations, which are located in Arkhangel'sk, Vladivostok and Moscow. The "COSPAS-1" satellite was placed into orbit in June of 1982. Although this satellite had a rated service life of 2 years, it is still in operation and there is reason to think that it will retain its operational fitness at least until the end of 1984, according to Doctor of Technical Sciences Arnol'd Selivanov. He mentioned that the USSR is preparing in good time for the replacement of satellites in the system. The receiving stations in Arkhangel'sk and Vladivostok are now being equipped and will be fully ready to operate at the end of 1984.

It was reported at the conference that tests of radio buoys operating on two frequencies have been conducted by Bulgarian specialists in the Black Sea, in the Bosporus and Dardanelles straits, and in the Atlantic Ocean. Lithium batteries developed for the buoys' emergency transmitters are said to have performed particularly well in these tests. Problems of the upcoming experimental-operation stage of the system were discussed and a memorandum on mutual understanding was signed at the conference. This memorandum defined procedures for joint work during the period up to 1990.

FTD/SNAP
CSO: 1866/67

CONFERENCE ON SPACE MATERIALS SCIENCE

Leningrad LENINGRADSKAYA PRAVDA in Russian 17 Nov 84 p 1

[TASS Report]

[Text] Moscow, 16 November--An international conference which examined problems of joint research by scientists of socialist countries in the field of space materials science has ended. Taking part in the conference were specialists of Bulgaria, Hungary, Vietnam, the German Democratic Republic, Cuba, Poland, Romania, the Soviet Union and Czechoslovakia.

The participants outlined a program of further joint scientific experiments and discussed prospects for the development of cooperation within the framework of the "Intercosmos" program.

FTD/SNAP
CSO: 1866/67

CONFERENCE ON LASER METHODS FOR EARTH STUDY

Tashkent PRAVDA VOSTOKA in Russian 17 Nov 84 p 2

[Text] An all-union seminar-conference on the topic "Problems of Aerial Probing of the Earth's Surface," which lasted 3 days, ended in Tashkent on 16 November. Timely questions of the utilization of lasers were examined in papers and reports given by F. V. Bunkin, corresponding member of the USSR Academy of Sciences, and other prominent scientists from Moscow, Leningrad and union republics.

Participants in the seminar-conference were familiarized with the work of a number of scientific and higher educational institutions of Tashkent, with equipment for studying the Earth's surface with lasers which has been developed at these institutions, and with the employment of this equipment in the economy.

Pilot-Cosmonaut of the USSR V. A. Dzhanibekov took part in the work of the seminar-conference.

FTD/SNAP
CSO: 1866/67

NEW CENTER FOR AEROSPACE AGRICULTURAL DATA

Moscow IZVESTIYA in Russian 9 Dec 84 p 3

[Article by I. Andreyev]

[Excerpt] The board of the Ministry of Land Reclamation and Water Resources has decided to establish a center for the routine processing and utilization of aerospace information.

L. G. Balayev, a member of the All-Union Academy of Agricultural Sciences and the director of the All-Union Scientific Research Institute of Hydraulic Engineering and Land Reclamation imeni Kostyakov, said: "The need for this center is enormous. Not only scientists but also farmers already appreciate the advantages of aerospace methods for determining the most important characteristics of soils. Take water reserves, for example. An airplane with a radiometer on board--an instrument which measures the amount of natural radio emission of any body, including soil--in a matter of hours surveys enormous areas, providing not just a sampling of water-content data, but a complete, whole-area picture. Even more effective are spacecraft. Even now, aerospace methods can lead to a 20- to 30-fold reduction in the volume of conventional field-survey work. In the future, we will obtain an even greater amount of high-quality and detailed information from space. The problem lies in its processing--in the interpretation of photographs, radiometry data, and visual observations by cosmonauts. It is furthermore important to give meaning to this diverse information, to formulate recommendations, and to make them available to those people who will in the final analysis make the decision to carry out a particular land-reclamation measure."

"I am convinced that as far as the needs of land reclamation and water resources are concerned, space technology has by far not demonstrated all its possibilities yet," said V. V. Gorbachev, head of one of the institute's laboratories. "They are limited by the capabilities of ground-based services, in particular, our decoding and analysis services. The center will contribute not just to the more rapid and accurate processing of the information, of which, by the way, there is no shortage even now, but also to the solution of qualitatively different problems. For example, to create a data bank which would contain information about literally all the fields in agricultural use in the country.

"We are now engaged in the development of fundamentally new kinds of surveying from satellites or manned spacecraft. Radar equipment will be able to monitor the Earth with high resolution not only at any time of day or night, but also in any weather, even through cloud cover. On the basis of our recommendations, specialists of the USSR and the German Democratic Republic are developing a new camera, the photographs of which will be partially processed on board the spacecraft. Both in space and on Earth, the laborious and tedious work of image interpretation will be done electronically."

FTD/SNAP
CSO: 1866/67

IONOSPHERE EFFECTS MAY REPLACE SOME COMMUNICATIONS SATELLITES

Moscow SOTSIALISTICHESKAYA INDUSTRIYA in Russian 20 Dec 84 p 6

[Article by V. Lagovskiy]

[Excerpt] "If we were able to see in the radio-frequency region, our atmosphere would not appear to us to be so transparent," said the scientist. "People would see the sky as if from the bottom of a pool, the surface of which is crossed by waves, ripples and all kinds of eddies."

The speaker was Candidate of Physical-Mathematical Sciences N. Borisov, a senior science associate of the USSR Academy of Sciences' Institute of Earth Magnetism, the Ionosphere and the Propagation of Radio Waves. I met with him and his colleagues at the "Soyka-6000" ionosphere probing station near Moscow, where antennas and sensitive electronic equipment are continuously monitoring the slightest changes in the ionosphere.

"For a long time, it was believed that the more powerful the transmitted radio signal, the louder will be its reception," continued the scientist. "But it turned out that such a relationship is maintained only up to a certain limit. Then something strange happens--the signal in the receiver gets weaker. Why? There have been many attempts to explain this phenomenon. But who would have thought that the cause of the troubles was--the radio beam itself.

"Studies conducted at the Moscow and Gor'kiy probing stations helped reveal this culprit. They have demonstrated that a powerful radio wave concentrates plasma into a cluster, the formation of which was previously attributed only to cosmic rays. Like some kind of 'lens,' this cluster then scatters the radio beam.

"This phenomenon has become the basis for a bold project. As envisaged by scientists, its implementation will make it possible to dispense with many communications satellites."

Doctor of Technical Sciences L. Lobachevskiy, the institute's deputy director, joined the conversation: "Imagine that we have beamed a powerful radio-wave pulse to a certain point in the ionosphere and created there a plasma cluster--a cloud of 'hot' charged particles. It can serve as an

excellent 'mirror' for TV waves. What is more, one can give this 'cloud-mirror' such shapes and properties that it will reflect radio and TV signals toward very specific areas on the Earth's surface."

The ionosphere is our reliable shield against destructive cosmic rays. Won't we damage it by such active interference?

"I knew that you would ask about this," smiled the scientist. "But judge for yourself: powerful electromagnetic pulses increase the concentration of ions in near-Earth plasma, and hence also its protective properties.

"The goal of the studies being conducted by the scientists is not only to get to know 'our own house' better. The problems they are solving include such practical ones as the prediction of disruptions in radio communication, as well as almost fantastic ones. In plans for the future, mankind places high hopes on orbiting power stations with gigantic solar-cell panels. The power produced on them is to be transmitted to Earth by means of microwave beams. But how will these beams pass through the ionosphere? What changes will they produce in it? How can undesirable aftereffects be avoided? Science must find answers to these and many other questions."

FTD/SNAP
CSO: 1866/67

UDC 551.509.313.001.572

OPTIMIZATION OF SYSTEM FOR OBSERVING NORTHERN HEMISPHERE ATMOSPHERIC PRESSURE FIELD

Moscow ISSLEDOVANIYE ZEMLI IZ KOSMOSA in Russian No 3, May-Jun 84 (manuscript received 28 Nov 83) pp 3-13

BELYAVSKIY, A. I. and POKROVSKIY, O. M., Main Geophysical Observatory imeni A. I. Voyeykov, Leningrad

[Abstract] Different methods for optimization of the collection of remote sensing data on the H_{500} geopotential field in the northern hemisphere are discussed. In the different variants in each case the aerological network is taken into account or is excluded. Depending on the satellite measurement scheme selected, the role of the aerological network will vary. For example, some satellite information is presently collected only over the oceans, but it is shown that even with availability of data from the surface aerological network remote measurements should be made over continental regions with a relatively low density of such stations. In one version which includes aerological stations the optimization scheme ensures a reduction in the volume of collected information by a factor of 1.5 with an accompanying increase in reliability. Then it is shown that an identical improvement is possible without including the aerological network. The principal result of the study was the development of a method for organizing optimum spatial schemes for collecting data from remote sensing of the geopotential field with allowance for the aerological network of stations. With a 30-50% reduction in the volume of collected satellite information it is possible to have essentially the same level of analytical error with a higher reliability than would be provided by a system providing for uniform hemispherical coverage. Figures 4; references 11: 9 Russian, 2 Western.
[170-5303]

UDC 551.593:629.78

RESEARCH ON ATMOSPHERIC DUST FORMATIONS USING SATELLITE OBSERVATION DATA

Moscow ISSLEDOVANIYE ZEMLI IZ KOSMOSA in Russian No 3, May-Jun 84 (manuscript received 21 Dec 83) pp 14-17

IVANCHIK, M. V., KLYUSHNIKOV, S. I., KROVOTYNTSEV, V. A. and SEREBRENNIKOV, A. N., Marine Hydrophysical Institute, Ukrainian Academy of Sciences, Sevastopol

[Abstract] Photoimages received from meteorological satellites in many cases are characterized by a lack of contrast between the sea and land along the western coast of Africa to the south of Cape Verde (a phenomenon observed in other coastal sectors as well). Such a case was studied using data from the "Meteor" artificial earth satellite (visible range 0.5-0.7 μm). A photograph taken on 2 May 1983 is used as an example. The photograph shows three types of cloud cover. In the central part of the photograph there is a cloudless zone in which the boundary between continent and sea is completely obscured. The reasons for this obscuring of the shoreline were investigated by processing the image on an electronic computer. At the time of reception the satellite data were simultaneously registered with a phototelegraphic apparatus in the form of a negative photoimage and on a computer magnetic disk in digital form quantized at 128 levels. The brightness of each element on the photograph corresponded to a definite quantization level. The maximum contrast of the central part of the photograph in the region of shoreline obscuring was 25 gradations (between the 15th and 40th quantization levels). A special formula was used in extending the dynamic range of the central part of the photograph from 25 to 70 gradations. A special program made it possible to define a wedge extending to the west of Africa. Brightnesses were determined in grid squares measuring 0.4 x 0.4°. The length of the area was 870 km and the width at the base was about 650 km. It differed from clouds in its uniformity and lesser brightness of its central part and evidently represented a dust formation. This conclusion was confirmed by on-shore surface-level meteorological observations. Figures 2; references: 5 Russian.
[170-5303]

UDC 528.7:91

STUDY OF VOLGA RIVER DELTA USING SPACE PHOTOSURVEY MATERIALS

Moscow ISSLEDOVANIYE ZEMLI IZ KOSMOSA in Russian No 3, May-Jun 84 (manuscript received 20 Apr 83) pp 27-32

KRASNOZHON, G. F. and SOKOLOV, Yu. S., Water Problems Institute, USSR Academy of Sciences, Moscow

[Abstract] Some aspects of the compilation of hydrographic maps of the delta regions of major rivers are examined. A compiled map of the delta region of the Volga is used as an example. The Volga delta is highly complex, having 260 large and moderately large distributaries. The boundaries between the distributaries and shoreline are very unstable and to a great extent dependent on water discharge, sea level, wind direction and velocity in the coastal region. Accordingly, mean water levels and outlines of islands must be reduced to a definite date. A map can be compiled precisely only when quasisynchronous prints are available. Such a map must show distribution of relief and position of the principal relief forms; their changes are indicative of the dynamics and trend of delta-formation processes. Negative relief forms must be defined. Map compilation requires formulation of a system of requirements for videoinformation. It is necessary to use photoimages obtained in different years but at corresponding times during the spring and summer-autumn period. The Volga River mouth was mapped using more than 200 panchromatic and 20 spectrozonal photographs at 1:1,000,000 scale or larger taken with different cameras in late May 1975, supplemented by photographs taken in the ice-free period 1974-1976. Aerovisual observations were made for studying direct and indirect interpretation criteria for identifying features on space photographs. The map compilation scale was 1:200,000. The final map (a fragment of which is reproduced in the article) represents the state of the hydrographic network of the Volga delta as of late May 1975). Figures 1; references: 10 Russian.
[170-5303]

UDC 551.244:629.78(574.1)

USE OF SPACE INFORMATION IN PETROLEUM- AND GAS-PROSPECTING WORK (EXAMPLE OF SOUTHERN MANGYSHLAK)

Moscow ISSLEDOVANIYE ZEMLI IZ KOSMOSA in Russian No 3, May-Jun 84 (manuscript received 28 Nov 83) pp 33-38

VOROB'YEV, V. T. and ORUDZHEVA, D. S., Geology and Exploitation of Fossil Fuels Institute, Moscow

[Abstract] Space information makes it possible to reveal new features of the geology of petroleum and gas regions. The Mangyshlak region was used as an example revealing the effectiveness of its use in exploration work in

already known producing regions. Southern Mangyshlak is one of the most important such regions in Kazakhstan and it has been relatively well studied by geological and geophysical methods. High-resolution space photographs are available for the area. They were used in studying the distribution and inheritance of structures, vertical neotectonic and recent movements, distribution of zones of compression and dilatation, nature and density of dislocations and relationship of known petroleum and gas deposits to them. Space photographs (in combination with a structural-geomorphological analysis) made it possible to compile a neotectonic map, a map of recent movements and a map of the density of lineaments and recent zones of compression and dilatation (Figures 1-3 in text). In the interpretation of space photographs the following operations were performed: ranking of lineaments and annular photoanomalies; analysis of hypsometric position and dissection of defined blocks for determining amplitudes of vertical neotectonic and recent movements; study of microrelief, species composition of vegetation, nature of ground cover and degree of ground moistening. For example, the amplitudes of recent vertical movements were qualitatively determined by interpretation of space photographs on the basis of relief microdissection. Recent compressional and dilatational zones were interpreted by analysis of relief microforms, degree of moistening and nature of changes in plant communities. The article illustrates how space photographs make it possible to collect new data on the geological structure of already known petroleum-producing regions. The detected petroleum and gas deposits in the Mangyshlak Basin are associated with zones of major neotectonic faults and recent dilatations, regions of positive recent vertical movements and local weak neotectonic uplifts and territories with average fracturing. Such work made it possible to define a number of areas apparently suitable for detailed seismic work (designated in Figure 2). Figures 3; references: 12 Russian. [170-5303]

UDC 551.25:629.78

EXAMPLE OF JOINT USE OF DATA FROM SURFACE STUDIES AND SPACE PHOTOGRAPHS IN INVESTIGATING DYNAMICS OF ZONE OF NORTH ZERAVSHAN SEISMOGENIC FAULTS

Moscow ISSLEDOVANIYE ZEMLI IZ KOSMOSA in Russian No 3, May-Jun 84 (manuscript received 1 Aug 83) pp 39-43

LAVRUSEVICH, A. I. and BUZRUKOV, D. D., "Priroda" State Scientific Research and Production Center

[Abstract] In the North Zeravshan fault zone the most important structural elements are dislocations, movements along which in large part determine the structural plan and geomorphological features of this area. The results of traditional surface geological research in this region, as well as information obtained from medium-scale black-and-white space photographs taken from a "Cosmos" satellite and the "Salyut-6" orbital station, were used in the study of key features in this area. The Zeravshan and Zakhmatabad faults are the most important of such features. The geology and recent movements

of these features are described. Space photograph interpretation yields much interesting and valuable information, such as an unusual configuration of the valleys of the left tributaries of the Zeravshan River. The lower reaches of the valleys are deflected to the right relative to their upper reaches. Interpretation of the drainage pattern in general revealed the important role of strike-slip movements in the zone and significant horizontal displacements during the recent tectonic stage. The recent tectonic activity in this zone, manifested in the landscape and apparent on space photographs, is responsible for its high seismicity. Such studies are required in the light of proposed hydraulic construction on the Zeravshan River for the purpose of regulating its runoff. Figures 2; references: 16 Russian.
[170-5303]

UDC 528.94:629.78

RELATIVE GEOLOGICAL INFORMATION YIELD FROM SMALL-SCALE MULTIZONAL SPACE IMAGES (EXAMPLE OF FERGANA DEPRESSION AND ITS MOUNTAINOUS MARCINS)

Moscow ISSLEDOVANIYE ZEMLI IZ KOSMOSA in Russian No 3, May-Jun 84 (manuscript received 22 Nov 83) pp 44-49

AZIMOV, B. G., Geology Institute, USSR Academy of Sciences, Moscow

[Abstract] More than 40 sets of space photographs covering the territory of the Fergana intermont depression and its mountainous margins were analyzed for clarifying the relative yield of geological information and the nature of image generalization on small-scale space photographs depending on change in spectral range. The photographs used were from satellites of the "Meteor-Priroda" type carrying multispectral TV apparatus and taking in four zones of the visible and near-IR ranges (0.5-0.6, 0.6-0.7, 0.7-0.8 and 0.8-1.1 μm). Summer photographs were used. The spectral brightness coefficient (SBC) was used as the basic parameter. A graph shows the change in spectral brightness coefficients of geological-geomorphological and other natural features as a function of the spectral range used. Four types of photoanomalies were discriminated. Curves (I-I, II-II, III-III, IV-IV) for the four types reveal distinctly different averaged SBC, indicating that in the visible range (0.5-0.7 μm) geological-geomorphological features are easily differentiated on the basis of reflectivity. This makes it possible to interpret elements of Quaternary geology and relief. In the spectral range 0.7-0.8 μm the averaged SBC curves are close so that the contours of geological-geomorphological features are blurred. In the near-IR (0.8-1.1 μm) there is a minimum of information on surface geological-geomorphological features, but lines and bands correlating with zones of deep faults, uplifts and depressions of the buried basement stand out. Figures 1; references: 6 Russian.
[170-5303]

UDC 551.52

CHOICE OF OPTIMUM PAIRS OF SPECTRAL INTERVALS FOR IR-RANGE SURVEY OF EARTH'S SURFACE

Moscow ISSLEDOVANIYE ZEMLI IZ KOSMOSA in Russian No 3, May-Jun 84 (manuscript received 24 Oct 83) pp 50-59

AREF'YEV, A. V., VLASOV, V. P. and KARASEV, A. B., Moscow Physical Technical Institute

[Abstract] An analysis of the possibilities of a two-channel method for measuring T_s (surface temperature) and C_s (temperature contrast) in the atmospheric transparency windows is given. In detecting surface features on the basis of their contrasts and in determining their T_s it is necessary that the influence of the atmosphere be minimized. This can be achieved when an appropriate choice is made for the spectral intervals of instrument response. It was found that the proper choice of a pair of spectral intervals can reduce the error in the two-channel method to approximately 0.40 K. Two factors are decisive: the intervals must be selected at different ends of the most transparent part of the spectrum 10.3-12.5 μm and the corresponding brightness temperatures T_1 and T_2 must differ sufficiently in magnitude. Specific examples are cited. It is shown that the use of the two-channel method considerably reduces both the error in determining surface temperature and the minimum detectable thermal contrasts in comparison with the single-channel method. It was possible to determine optimum pairs of intervals for which the error in retrieving T_s, with allowance for water vapor and aerosol, both in the lower layers of the atmosphere and in the stratosphere, does not exceed 0.5-0.7 K. In the absence of high-altitude aerosol the error in determining T is about 0.40 K. The error in retrieving T_s in the two-channel method is attributable primarily to aerosol variation. The influence of both water vapor and other atmospheric components on the accuracy of the method is taken into account with an error less than 0.1 K. The use of optimum intervals minimizes the error δT_0 caused by deviation of surface emissivity from unity. For a water surface δT_0 does not exceed 1.0 K. The substantial increase in accuracy in determining T_s by the two-channel method will make it possible to decrease the minimum detectable contrasts. Figures 5; tables 2; references 9: 2 Russian, 7 Western.
[170-5303]

UDC 528.72(202):535.36

EVALUATING RADIATION DISTORTIONS OF OPTICAL IMAGE OF EARTH'S SURFACE IN HORIZONTALLY INHOMOGENEOUS ATMOSPHERE

Moscow ISSLEDOVANIYE ZEMLI IZ KOSMOSA in Russian No 3, May-Jun 84 (manuscript received 18 Aug 83) pp 72-76

MISHIN, I. V., All-Union Scientific-Technical Information Center, Moscow

[Abstract] A model of the atmosphere with a vertical stratification of the density of scattering particles (without allowance for its horizontal inhomogeneities) is used in existing algorithms for compensating radiation distortions of the optical image of the earth's surface. In order to ascertain the practical efficiency of these algorithms a study must be made of the influence of horizontal variations in the density of scatterers on the brightness of short-wave radiation measured from artificial earth satellites. The author has already published a mathematical model making this possible (I. V. Mishin, ISSLED. ZEMLI IZ KOSMOSA, No 4, pp 95-104, 1982). This model has now been applied in evaluating radiation distortions of the optical image caused by horizontal inhomogeneities in the atmosphere. Albedo variations of the earth's surface are neglected in order to simplify computations. It was found that horizontal inhomogeneity of the atmosphere exerts the greatest influence on J (brightness of ascending radiation) in the case of small $\overline{q}$ (surface albedo). With an increase in $\overline{q}$ this influence attenuates and beginning with $\overline{q} \sim 0.4$ it may even become insignificant. For observation directions around the nadir the nonlinearity of the system for the transfer of the optical image by the earth's surface in a horizontally inhomogeneous atmosphere is small and in remote sensing in the optical range of the spectrum a linear model can be used. Tables 1; references: 8 Russian.
[170-5303]

UDC 631.4:629.78

VARIABILITY OF COEFFICIENTS OF SPECTRAL BRIGHTNESS OF SOILS

Moscow ISSLEDOVANIYE ZEMLI IZ KOSMOSA in Russian No 3, May-Jun 84 (manuscript received 22 Nov 83) pp 77-82

FEDCHENKO, P. P. and BORISOVA, O. A., All-Union Scientific Research Institute of Agricultural Meteorology, Obninsk

[Abstract] A study was made of the laws of variability of the spectral brightness coefficient of a variety of soils in order to determine the influence of illumination conditions, degree of cultivation and moisture content on the total variation of the SBC of the investigated soils. Observations were made of three freshly plowed, but not moist, fields with different types of soils (soddy-podzolic, gray forest and chernozem). The

experimental fields were worked to an approximately identical degree with the maximum size of lumps not exceeding 6-10 cm. Measurements were made in clear weather with solar altitudes 38-41°. Time required for measurements in each field was 25-30 minutes. About 40 measurements were made in each field at points situated on a linear path at intervals of about 10 m. The SBC were determined using a six-channel lens photometer with a field of view of 30°, silicon photodetector and set of inference light filters with transmission maxima at 453, 503, 551, 602, 668 and 796 nm. The photometer field of view covered an area with a diameter of about 1 m. These investigations confirmed that solar altitude, soil moisture content and degree of soil working make the principal contribution to the total variability of the SBC of soils. The SBC of soil is acted upon simultaneously by two or three factors, not easily taken into account. Some of these factors, when present simultaneously, will compensate one another to some degree (solar altitude and soil moisture content), whereas others are superposed (moisture content and degree of working). A series of tables gives conversion factors for taking into account the simultaneous influence of two or three factors on the SBC of soil. For application of these factors it is necessary to have a priori information both on the state of the soils and on solar altitude. Tables 6; references: 4 Russian.
[170-5303]

UDC 681.3:518

EVALUATING IDENTIFIABILITY IN REMOTE SENSING PROBLEMS

Moscow ISSLEDOVANIYE ZEMLI IZ KOSMOSA in Russian No 3, May-Jun 84 (manuscript received 15 Jul 83) pp 83-88

GULYAS, O. and FARAGO, T., Central Meteorological Institute, Budapest

[Abstract] The main problem in image identification in remote sensing is the statistical differentiation of the numerical vectors of a multizonal survey as a function of their actual nature, as in the classification of different varieties of agricultural crops or stages in their growing season. Many factors determine the degree of identifiability, such as fluctuations of the spectral brightness of natural features, signal transformation during its passage through the atmosphere and its transformation in the survey apparatus. This article gives procedures for measuring the probability of error and more general mean risk functionals which can be used in measuring the degree of identifiability. The different steps in these procedures are outlined, such as the minimizing of the functional, and a probability density function is proposed for this purpose. The basis for the overall method is a successive approximations method for functionals of a broad class for measuring the quantity of information. A simple example of identifiability of real videoinformation is given (multizonal space survey from "Meteor" satellite with low-resolution scanner). Only a simple example is given: two classes corresponding to plowed and overmoistened fields. The method can be advantageously used in selecting optimum

spectral channels or their combinations and in solving similar problems in the processing of space videoinformation. Figures 3; references 11: 8 Russian, 3 Western.
[170-5303]

UDC 681.3:528

IDENTIFYING LAND USE STRUCTURES ON MULTIZONAL AEROSPACE PHOTOGRAPHS USING DIGITAL DATA PROCESSING

Moscow ISSLEDOVANIYE ZEMLI IZ KOSMOSA in Russian No 3, May-Jun 84 (manuscript received 5 Sep 83) pp 89-96

SCHMIDT, I. and STOYE, H., Geography and Geoecology Institute, GDR Academy of Sciences, Leipzig

[Abstract] A method is proposed for the interpretation of multizonal aerospace photographs for the purpose of identification of land use categories. The basis for the described method is the hypothesis that the real mosaic of land use is reflected by spectral and textural criteria, proximity and spatial position characteristics. The material used in the study was a multizonal space photograph taken in August 1978 with an MKF-6 camera from the "Salyut-6" station. The spectral zones 640-680 and 790-890 nm were selected for such processing because they contain the optimum of information for the interpretation of land use categories. An analysis was made of the correlations and so-called contingencies of brightnesses of the photograph, transformed to a digital form. The photograph extended from the suburbs of Leipzig far into regions of intensive agricultural land use. A land use map of the area, compiled by ordinary procedures at a scale of 1:50,000, was available for comparative purposes. Ten different classes of land use were defined. The spatial distribution of brightnesses of typical structures was determined. Table 1 gives types of brightness combinations in the spectral zone 640-680 nm; Table 2 gives corresponding material for the spectral zone 790-890 nm. The information best revealed in these two spectral zones was carefully evaluated. In the spectral zone 640-680 nm in 11 of 13 typical brightness combinations there was a predominance of agricultural land use, whereas in the spectral zone 790-890 nm a greater role was played by typical brightness combinations with dispersed structures. There was good agreement between the surface map and the interpreted land-use types. Figures 1; tables 4; references 8: 1 Russian, 7 Western.
[170-5303]

UDC 528.7:681.3

EXPERIENCE IN AUTOMATION OF DATA PROCESSING IN INTERPRETATION AND DEFINING OF LINEAR ELEMENTS FROM SPACE PHOTOGRAPHS

Moscow ISSLEDOVANIYE ZEMLI IZ KOSMOSA in Russian No 3, May-Jun 84 (manuscript received 29 Dec 83) pp 97-105

GOL'TVEGER, V. Ya., IL'IN, V. A. and KUNINA, N. M., "Aerogeologiya" Geological Production Association, Moscow

[Abstract] Two important aspects of geological interpretation of space photographs are examined: automation of some time-consuming steps in the processing of interpretation data (fissuring, faults) and automated discrimination of linear elements directly from space photographs. The work was done using the automated image processing system developed at the Information Transmission Problems Institute. The experiment was made with a space photograph of the Kola Peninsula enlarged to a scale of 1:500,000. A fragment covering an area 35 x 35 km was subjected to detailed interpretation. This was used in compiling a map of fissures for demonstrating the possibility of automatic processing: computer compilation of a density map, a map of fissures with particular directions and rose diagrams. This was followed by detailed comparison with results obtained in an experiment with automated discrimination of linear elements. The procedures for preparing each of these maps are described in detail; examples of each are presented. Computer interpretation is characterized by great detail; linear elements, for example, are not apparent as extended lines, as in visual interpretation, but as short segments. The method, however, has serious limitations, its applicability being limited to those cases when most of the brightness drops on a photograph are caused by linear elements and the brightness drops caused by nonlinear elements are negligible. The methods do not make it possible to differentiate the discriminated linear elements, such as separation of structural lines from faults or tectonic fissuring, and it is impossible to reject elements of anthropogenic features. On the other hand, the method is characterized by speed of processing, reproducibility of the results and sensitivity of the procedures, which gives additional information in cases when the human eye perceives drops in brightness poorly or not at all. Figures 6; references 6: 5 Russian, 1 Western.
[170-5303]

UDC 518

USING SM-4 - 'OMEGA' SYSTEM IN CHECKING AND EDITING DIGITAL TERRAIN INFORMATION

Moscow ISSLEDOVANIYE ZEMLI IZ KOSMOSA in Russian No 3, May-Jun 84 (manuscript received 28 Dec 83) pp 106-114

KALANTAYEV, P. A., MIKHAL'TSOV, E. G., PYATKIN, V. P., SALAVATOV, R. M. and CHUBUKOV, V. G., Computer Center, Siberian Department, USSR Academy of Sciences, Novosibirsk

[Abstract] Improvements have been made in the apparatus and programs used in the checking and editing of digital terrain information (DTI) in an interactive regime. Interactive graphic displays of the vector type are now used in most such work, but are encumbered by many shortcomings such as limitation of the total length of lines forming the image appearing on the display screen, presence of only one or two colors from which the image is formed, impossibility of output of a half-tone image to the screen, absence of filling of the image of areal features, and others. These limitations have been eliminated by the introduction of a new interactive color screen display used with the "Omega" specialized half-tone color terminal which is included in a complex for the interactive processing of images which operates with an SM-4 computer (a block diagram of the SM-4 - "Omega" system accompanies the text and serves as a basis for a detailed discussion of operation of this complex). Image processing is on an element-by-element basis at the rate of television scanning. A special interface is used in transmission of digital information and controlling information between the SM-4 computer and the "Omega" terminal. The "Omega" terminal is part of a complex intended for the processing and reproduction of digital images. The number of jointly processed images is three, with the possibility of expansion to 16. Figures 5; references: 5 Russian.
[170-5303]

UDC 528.2:629.78

COMPUTING PARAMETERS CHARACTERIZING POSSIBILITY OF PLANETS FALLING IN STAR CAMERA FIELD OF VIEW DURING SPACE SURVEY

Moscow IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY: GEODEZIYA I AEROFOTOS"YEMKA in Russian No 3, May-Jun 84 (manuscript received 18 Jul 83) pp 85-89

ZHURKIN, I. G., professor, doctor of technical sciences, and KUZ'MINYKH, V. A., docent, candidate of physical and mathematical sciences, Moscow Order of Lenin Institute of Geodetic, Aerial Mapping and Cartographic Engineers

[Abstract] In order to select the optimum conditions and to formulate a program for a survey of planets from a space vehicle it is necessary to know the probability of entry of planets into the star camera field of view (SCFV) and

the time of presence of a planet in the SCFV. The authors first solve the problem of determining the probability of at least one planet falling in the SCFV; then an expression is derived for determining the probability that one definite planet will enter the field of view. As a point of departure it is assumed that the optical axis of the star camera has a random orientation at a fixed moment in time. It is further assumed that the point of intersection of the optical axis of the star camera and the celestial sphere at a given moment in time t is uniformly distributed in the region L of possible values of the angular coordinates α, δ (right ascension, declination). By integration of a system of equations of motion for the large planets it is possible to determine the geocentric radius-vector corresponding to the moment in time t. Thereafter a number of simple steps make it possible to ascertain the probability of at least one planet falling in the SCFV. P (probability) values, computed using the algorithm presented in this article, are given in five tables. The data presented in these tables make it easy to select the optimum regimes for star camera operation for the registry of at least one planet. Then a solution of the second problem (determination of the time of transit of a planet into the SCFV) is presented. A number of assumptions are made: during the considered time interval the planetary motion is Keplerian; the SCFV is a right circular cone whose apex coincides with the center of the earth's mass; the rotation of the optical axis of the star camera occurs with a period equal to the period of revolution of the satellite carrying the star camera. Sample computations are presented. An expression is derived for the presence of a planet within or at the boundary of the cone at a stipulated time. Tables 5; references: 3 Russian.
[181-5303]

UDC 528.221 528.28

ONE ASPECT OF DETERMINATION OF DIRECTION OF SPACE SURVEY BASE FROM PHOTOGRAPHS OF PLANETARY SURFACE AND STAR SKY

Moscow IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY: GEODEZIYA I AEROFOTOS"YEMKA in Russian No 3, May-Jun 84 (manuscript received 10 Feb 83) pp 76-78

SHCHERBAKOV, M. I., candidate of technical sciences, Moscow Order of Lenin Institute of Geodetic, Aerial Mapping and Cartographic Engineers

[Abstract] The use of two rigidly coupled cameras makes it possible to determine the directions of satellite-centered vectors $\bar{\rho}_{ij}$ to points on the planetary surface in an inertial coordinate system. The $\bar{\rho}_{ij}$ vectors can be used as initial information for differential refinement of the orbit of an artificial planetary satellite. However, in such a form the initial information leads to an unwieldy system of correction equations because the $\bar{\rho}_{ij}$ values are functions of both the coordinates of points on the planetary surface and the coordinates of the artificial planetary satellite. Conversion to an orbital chord would be optimum. A rigorous determination of the orbital chord $\Delta\bar{r}$ is impossible but an approximate determination is possible by introducing into the vectors $\bar{\rho}_{1A_1}$ and $\bar{\rho}_{1C_1}$ (or $\bar{\rho}_{2A_2}$ and $\bar{\rho}_{2C_2}$) corrections

taking planetary rotation into account. However, this requires a knowledge of the coordinates of points on the planetary surface in order to compute the corrections. Difficulties can be avoided by finding a solution in a coordinate system rigidly coupled to the planet. In such a coordinate system it is possible to determine some vector in a general case not coinciding with the orbital chord in this system; this vector is called the space survey base. An expression is derived relating the orbital chord and the space survey base. This space survey base can be used in differential refinement of the artificial planetary satellite orbit. Figures 2; references: 1 Russian.
[181-5303]

UDC 550.83:550.814:551.243

INTERPRETATION OF SPACE PHOTOLINEAMENTS

Moscow SOVETSKAYA GEOLOGIYA in Russian No 9, Sep 84 pp 81-83

ROZANOV, L. N. and KALININA, I. N., All-Union Petroleum Scientific Research Institute of Geological Exploration (VNIGRI)

[Abstract] There is a definite pattern of space photolineaments, most of them having northeasterly and northwesterly strikes. These two main systems can be traced in all platform regions, many of them extending for great distances and intersecting regions not only of platforms, but also folded systems consisting of rocks of different age from ancient to Quaternary. However, these are not continuous lines but discontinuous fragments forming general systems. Unfortunately, these features have been interpreted in various ways. The authors contend that seismic observations along regional profiles can help in solving this problem: the results of interpretation of space survey data should be compared with seismogeological sections along regional profiles. Such comparisons show that space photolineaments coincide well with faults both in the upper part of the crust and at considerable depths (this is illustrated by specific cases, Figures 1 and 2 in the text). Thus, the study revealed that almost all lineaments coincide with dislocations or zones of increased permeability discriminated in the seismological sections, although not all the dislocations apparent in the sections are represented on space photographs. It can be postulated that only those dislocations appear at the earth's surface which are related to the most recent tectonic activation. Space photolineaments probably represent so-called planetary fissuring manifested in the entire crust or its greater part. The dislocations reflected on space photos and in seismic sections are for the most part zones of crustal dilatation and circulation of fluids. Figures 2; references: 8 Russian.
[20-5303]

UDC 551.461.7

ANALYSIS OF HYDROMETEOROLOGICAL CONDITIONS IN ANTARCTIC COASTAL WATERS ACCORDING TO DATA FROM HYDROLOGICAL AND SATELLITE OBSERVATIONS

Leningrad VESTNIK LENINGRADSKOGO UNIVERSITETA: GEOLOGIYA, GEOGRAFIYA in Russian No 3, Sep 84 (manuscript received 10 Sep 83) pp 96-99

GOLOSOV, V. V. and REBENKOVA, O. A.

[Abstract] The article gives a hydrometeorological description of the coastal region of Antarctica based on hydrological data obtained during the summer navigation season of 1980/1981, together with TV images of the Indian Ocean and Atlantic Ocean sectors of the Antarctic Ocean from the "NOAA," "Meteor-Priroda" and "Meteor-2" satellites. The geographic grid used made possible a referencing to the coastal zone with an accuracy to about 10'. This made it possible to give a monthly generalization of cloud cover conditions in the coastal area 0-40°, to detect the hydrological front in this region, to trace the destruction of the zone of drifting coastal ice in January and the appearance of young ice in early March and to draw conclusions concerning the nature of water circulation on the basis of movement of a gigantic iceberg. It was found that during the summer season there was a predominance of cloudless or nearly cloudless weather, evidence of calm hydrometeorological conditions in coastal areas, affording good conditions for interpreting hydrological fronts. TV photographs for the southwestern part of the Riiser-Larsen Sea made it possible to identify the position of the hydrological front (confirmed by subsatellite observations). The front separates cold coastal and heated waters in the central part and persists stably at 15°E for at least a month. The coastal region at 13°E becomes accessible for shipping beginning in the second 10-day period in January and therefore the length of the 1981 navigation season can be set at 1.5 months. In summer, drifting ice advances into this region from the east, making navigation more difficult, but breaking up and constituting no serious danger for shipping. Mapping of the trajectory of movement of an enormous iceberg in February-March 1981 confirmed the pattern of circulation determined from hydrological observations. Figures 2; references: 2 Russian.
[34-5303]

UDC 521.9

PRELIMINARY PROCESSING OF LASER RANGING DATA FROM LAGEOS ARTIFICIAL EARTH SATELLITE DURING SHORT MERIT PROGRAM OBSERVATION PERIOD

Moscow PIS'MA V ASTRONOMICHESKIY ZHURNAL in Russian Vol 10, No 5, May 84 (manuscript received 21 Nov 83) pp 397-400

NESTEROV, V. V., State Astronomical Institute imeni P. K. Shternberg, Moscow

[Abstract] The results of LAGEOS ranging during the period August-September 1980 consists of pairs of numbers: topocentric distances and observation times. The problems involved in the processing of these data are exceedingly complex: 400,000 observations were made with 12 NASA and 3 SAO stations involved. The author discusses the possible approaches which could be employed in preliminary processing and then outlines the procedures adopted at the State Astronomical Institute. This involved the recoding of all data into a form adopted for computer processing, their standardization and resorting. This work required about 40 hours of computer time. At the end of this first stage a mass of observational data was available which was encumbered by random and systematic errors. The "normal points" method was selected in order to improve accuracy, supplemented by the smoothing method proposed by J. Vondrak (BULL. ASTRON. INST. CZECHOSL., 20, 349, 1969). It was decided to use a smoothing interval of about 150 sec and a smoothing coefficient of 10^{-5}. Computations requiring about 80 hours of computation time yielded 5,985 normal topographic distances to LAGEOS with an accuracy to 2-10 cm. These distances are deemed suitable for checking various space geodesy algorithms. The data processing results are available to users upon request. Tables 1; references: 1 Russian.
[164-5303]

UDC 528.72

INCREASING THE ACCURACY OF PROCESSING RADAR PICTURES BY EXCLUDING SYSTEMATIC POINT COORDINATE ERROR COMPONENT

Moscow IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY: GEODEZIYA I AEROFOTOS"YEMKA in Russian No 4, Jul-Aug 84 (manuscript received 19 Aug 82) pp 65-72

YELYUSHKIN, V. G., engineer, and PRONIN, B. V., candidate of technical sciences

[Abstract] The relationship between the coordinates of points on the terrain and on a radar image contains significant random components due to various instabilities, noise and trajectory fluctuations. These errors can be reduced by considering the nature of the trajectory fluctuations. Such near-periodic oscillations contain a number of harmonic components. In order to develop a method for selecting a mathematical apparatus for their exclusion, the authors studied the influence of trajectory fluctuation

parameters on the nature of errors in the coordinates of points of radar images. Secondary processing of radar images by the use of the method developed can increase geometric accuracy by 20 to 30%. The effectiveness of the method is greater, the larger the radar image in comparison with the period of trajectory oscillations of the aircraft. Figures 4; references: 4 Russian.
[17-6508]

UDC 528.7(203)

CALCULATION OF IMAGE SHIFT IN PANORAMIC PHOTOGRAPHY

Moscow IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY: GEODEZIYA I AEROFOTOS"YEMKA in Russian No 4, Jul-Aug 84 (manuscript received 8 Apr 80) pp 81-89

MILLER, B. M., candidate of physical and mathematical sciences, MORSKOVA, M. N., engineer, and FEDCHENKO, G. I., engineer

[Abstract] A method is suggested for calculating the image shift in a panoramic photograph applicable to panoramic aerial photographs, though this does not limit the general nature of its applicability. A program was written in FORTRAN for the BESM-6 computer to implement the algorithm. The authors propose to continue analyzing various systems for compensating image shift in panoramic apparatus in order to select solutions most acceptable both from the standpoint of residual shift and from the standpoint of design complexities. Figures 3; references 7: 3 Russian, 4 Western.
[17-6508]

UDC 535:550.83

DETERMINING CHARACTERISTICS OF OPTICAL RADIATION REFLECTORS BASED ON RESULTS OF REMOTE SENSING

Moscow IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY: GEODEZIYA I AEROFOTOS"YEMKA in Russian No 4, Jul-Aug 84 (manuscript received 20 Dec 82) pp 93-98

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[Abstract] The planning of spacecraft remote sensing systems for studies of the earth requires the study of the reflective characteristics of natural objects. The problem arises of developing methods of determining informative parameters of objects. This formula is simplified if the characteristic experiment recorded is a measure of the directional properties of reflectors. This article studies one such characteristic, the directionality coefficient of the reflector. It can be determined by recording the back reflection index of an object being studied. A spacecraft flying past a reflector

illuminates it with laser radiation from a continuously changing angle. An algorithm is presented for estimating the absorbing properties of obstacles and determining the back reflection of the reflector. The results of experimental measurements allow determination of the parameters of surface unevenness. References: 6 Russian.
[17-6508]

UDC 529.9:528.711.1(202)

USE OF SPACE PHOTOGRAPHIC INFORMATION TO MAP PLANT COVER

Moscow IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY: GEODEZIYA I AEROFOTOS"YEMKA in Russian No 4, Jul-Aug 84 (manuscript received 28 Apr 83) pp 99-106

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[Abstract] Space photographs were interpreted in order to determine the types of plants present, reflecting adaptation of plants to existing conditions. The life form of plants is the basis of classification and reflection of the plant cover in state topographic maps. Therefore, possibilities were simultaneously studied for using space photographs in topographic mapping. Studies were performed using photographs made by the Salyut-5 space station of the arid zones of central Asia. Interpretation of the photographs allowed evaluation of the information on the plant cover for purposes of cartography. The use of space photographs has a number of advantages: possibility of determination of boundaries of plant cover with high accuracy; determination of boundaries of transitions difficult to distinguish from aerial photographs or even in the field; possibility of determining changes in types of cover resulting from changes in habitat; reflection of altitude belts in mountains which cannot be seen on aerial photographs due to the small territories they cover; reflection in morphologic structure of images of heterogeneities and complexities of the plant cover; integration of images, objectivizing the behavior of generalization of plant cover; and possibility of reflecting dynamics of plant cover, both natural and anthropogenic.
[17-6508]

SPACE POLICY AND ADMINISTRATION

CAREER OF SPACECRAFT DESIGNER BABAKIN RECALLED

Moscow IZVESTIYA in Russian 12 Nov 84 p 3

[Article by B. Konovalov and B. Mikhaylov, engineer]

[Text] Before 1965 the name of the designer Babakin was practically unknown among the ranks of space specialists. At that time he was still neither an academy member nor a doctor nor even a candidate of sciences. And it required the boldness and perspicacity of Sergey Pavlovich Korolev to put into the hands of an unknown engineer a tremendous scientific and technical assignment--the creation of unmanned lunar and interplanetary spacecraft. Let us say at once that Korolev had reasons for his action, and the whole subsequent course of events confirmed the correctness of his choice.

A strong vote of confidence lends wings. And a person does what yesterday seemed impossible even to him. Babakin worked only 6 years as the chief designer of unmanned spacecraft, but what he managed to accomplish during those years staggers the imagination. The 15 vehicles that were created under his direction were a major contribution to the world's achievements in space flight, and the flight of each of them was a landmark event.

Let us recall. Luna-9--the first soft landing on the surface of another heavenly body. Luna-10--the first satellite of the Moon. Venera-4--the first parachute descent in the sky of Venus and the first direct investigations of its atmosphere.

The first travel on the moon in the history of mankind, the delivery of rocks from the Moon, the soft landing of a vehicle and the conducting of research on the surface of fiery Venus--all this was done by unmanned spaceships designed in the design office directed by Babakin, whose staff members just a few years earlier were acquainted with spaceships only through the newspapers.

How can their truly phenomenal success be explained? In the first place, of course, by the fact that it was a talented, competent group of workers, who had behind them vast experience in creating complicated technology. Of course, there are no miracles--a team consisting only of novices could not cope with such responsible tasks. But any team, even the most talented, can fully reveal its capabilities only if at its head there is a bright,

enterprising person who knows how to inspire people and imbue them with enthusiasm. Just such a leader was Georgiy Nikolayevich Babakin.

Moreover, in space technology the collective is a broader concept than just a design bureau. In order to create a spaceship one must be able to unite the efforts of tens of design bureaus, institutes and plants, to make them carry out their work efficiently and harmoniously and not just "by the book," but creatively, with enthusiasm, and one must not be to the slightest degree aloof from the overall operation.

We know that this is far from simple. But Georgiy Nikolayevich succeeded. And it is interesting that in contrast with stern, imperious, demanding leaders of Sergey Pavlovich Korolev's type Babakin was a very gentle person, with a markedly polite manner of addressing people.

Gentleness is not always weakness of will. Babakin was a strong-willed person and knew how to reach a set goal by his own unorthodox methods. All who were associated with him felt the charm of his personality, his friendliness, his erudition and his determination to assume responsibility in difficult situations.

He was a natural genius. His entire classroom education was seven grades and some four-month radio technician courses completed at age 16. Babakin completed the 10-year secondary school by examination, and he received his higher education diploma only at the age of 42, when he was already working as the head of a major scientific department. He was endowed by nature with tremendous abilities, a brilliant technical mind, a superior memory and an ability to absorb knowledge from books and from contacts with other people. And indeed, thanks to his self-education and natural talent, Babakin developed in himself the qualities essential for a chief designer.

Academician Georgiy Ivanovich Petrov, who, as the first director of the Space Research Institute of the USSR Academy of Sciences, met with Babakin, remarked that Georgiy Nikolayevich came close to the concept of the ideal chief designer.

"What was Babakin?" mused Petrov. "A scientist? An engineer? For a long time even practicing engineers have been elected to the Academy of Sciences. Examples? How about Tupolev? He didn't write any scientific works, but he was a full-fledged academician. To my way of thinking, Babakin was a scientist-engineer. Exactly that, a scientist-engineer. With a hyphen. He considered matters from the various sides, possessed the greatest breadth of view and by himself acquired an excellent mastery of many topics, especially problems of management..."

A designer of unmanned spacecraft always remains on Earth. It is his creation that goes into flight. And you can't stop a rocket. An interplanetary vehicle is not an airplane. You can't set it down on an airfield for modification. Therefore, in the creation of space equipment, as in no other field, the ruling principle of "measure seven times to cut only once."

Everything that can be tested must be tested on Earth. Everything that can be calculated must be calculated on Earth. In a word, everything that can be must be worked out on Earth to the point of crystal clarity.

The first thing that Babakin did when he was entrusted with a space project was to construct test stands for ground testing. At the facility there appeared a unique centrifuge capable of producing load factors of 300 G, simulating the whole "delight" of a vehicle's entry into the Venusian sky, and an altitude chamber in which were created conditions close to those that await a spacecraft in space...

It became the rule to construct tens of duplicates of each spacecraft for the most severe, fault-finding ground tests. Moreover, when the first "Babakin" Venera lifted off, its exact copy was "flying" in the altitude chamber on Earth. Before liftoff each team had trained on this double. And perhaps precisely for this reason the design bureau's first Venusian vehicle became the famous Venera-4, which astonished the whole world with its smooth descent into the sky of the distant planet.

Every chief designer has his own trademark in his work. It was characteristic of Babakin's style not to plan a spacecraft for the accomplishment of any single task, no matter how epoch-making, but to strive to build into each spacecraft the capability of its further development with minimal effort. This can be called the efficiency principle. In the design office it had a more prosaic name--maximal use of standardized units.

This was demonstrated most obviously and clearly in the second generation of lunar vehicles and in the Venusian descent vehicles.

It would seem as though they were completely different tasks--the retrieval of Moon rocks and the delivery onto the surface of the Moon of a self-propelled laboratory--the lunar rover. But actually they were accomplished with the help of one and the same landing stage. Figuratively speaking, only the "riders" were changed, and the "horse" remained one and the same.

Do you realize how much this saved? How many fewer drawings were needed, and how much less plant work, and how much less testing? And to a great extent thanks to this standardization Babakin's design bureau managed to withstand the fierce pace of solving ever newer and newer scientific problems.

Perhaps still more important was the ability of the enterprise to discover capabilities incorporated in the design of the existing vehicles. Let us follow the path of the Veneras. From Venera-4 to Venera-8 the overall mass of the vehicle did not change. It was from the beginning determined by the capacity of the carrier rocket. It would seem that there was a limit to what you could do here, but still the designers within the strictly imposed overall weight limit succeeded in making an ever more perfect descent vehicle accommodating scientific equipment for studies of Venus. Whereas the descent vehicle of Venera-4 retained its ability to function through part of its descent, the vehicle of Venera-7 was still alive and working on

the surface of the planet for 23 minutes! And this with the pressure on it equaling that of a column of water several kilometers high and the temperature of its surroundings capable of melting zinc and lead. And yet in their dimensions the vehicles were practically identical. And the further successes of Soviet unmanned spacecraft created in Babakin's design bureau even after him were so impressive that thanks to the scientific results obtained as a whole Venus began to be called the "Russian" planet.

This line of Soviet astronautics is brilliantly confirmed today as well--black-and-white and color panoramas of the mysterious world of Venus, chemical analysis of rocks in a laboratory delivered to the planet, a radar map taken from Venusian orbit; all this is the pride of Soviet astronautics and an outstanding contribution to the world's treasury of knowledge.

In the Long-Range Space Communications Center after the flight of Venera-5 and Venera-6 Babakin said to one of us: "The essential quality for a designer is to have an obsession. If a person does not believe in the possibility of creating a vehicle, if he does not burn with this idea, he will hardly be a good designer. To the honor of our team it must be said that this quality is present in the designers in the enterprise. And it helps us tremendously."

He held his collective in high esteem. And the collective held its leader in high esteem. This is what is said of Babakin by those who worked long years side by side with him, who shared with him the joys and difficulties of the difficult path of creation. For as we know, the path to the stars leads through thorns.

"Babakin established an exceptional atmosphere of creative enthusiasm, elation and desire to solve problems in the very best manner."

"He knew that the majority opinion often can lead to an already known stereotype. Original opinions interested him much more."

"Georgiy Nikolayevich might not like a person (such a case was very rare), but he nevertheless listened to his opinion attentively. He possessed an invaluable quality--he immediately grasped a good idea."

"It was easy to work with Georgiy Nikolayevich--he had the authority of intellect, and what is very important, he didn't overwhelm the person he was talking with, he knew how to listen."

"Georgiy Nikolayevich's strength lay in the fact that he could look sufficiently far into the future and assess the more necessary, real and urgent in that future..."

No one who worked with Babakin will ever forget him. On the Moon and on Mars there are craters that bear his name. They are alongside the craters of Tsiolkovskiy and Korolev.

And this fact by itself is the best evidence of the importance of his contribution to the development of cosmonautics, the contribution of Hero of Socialist Labor, Lenin Prize laureate and USSR Academy of Sciences associate member G. N. Babakin.

Babakin lived 57 years. These days we would be celebrating his 70th birthday.

We know what he would say at the celebration if he were alive. Let us quote the words from his letter to his son, words that even today seem directed to all who are entering the brotherhood of space designers: "Never forget the people around you, and remember that you by yourself, no matter how smart you might be, will not be able to do anything without the team. On this point, self-taught persons who working in isolation were able to 'put shoes on fleas' are passing into the realm of legend. The profession that is mine and will be yours looks to the coordinated work of large teams consisting of people of various types. We must find our place in the team independently of the position we occupy and earn the recognition of those who are standing beside us. A kind way of dealing with people and good qualifications will assure you of recognition; you will be necessary to society, and that is the main thing."

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CSO: 1866/41

ASSOCIATES RECALL CAREER OF SPACECRAFT DESIGNER BABAKIN

Moscow SOVETSKAYA ROSSIYA in Russian 11 Nov 84 p 4

[Article compiled by M. Borisov and A. Nemov: "The Conquest of Infinity"]

[Text] A. Razikov, engineer.

At the age of 15, Yura Babakin finished, as they said back then, the second stage: that is, the seventh grade. This was in 1929. And he, considering the fact that his family was living under quite straitened material conditions, decided to master some specialty quickly and go to work. As far as the specialty was concerned, he never wavered: of course he wanted to learn about radio. He and I took radio assembler courses that were organized by the Society of Friends of Radio's Central Radio Laboratory.

We learned "avidly" every month. It was so fascinating and interesting. It was only when we took the courses that we understood that we knew nothing about radio, despite our amateur successes. We were dilettantes. But now we began to understand what was what, felt a stormy rush of forces, and wanted to assemble different circuits and tune and test them. Once we even made feeble, low-powered transceivers. For talking with each other. And we used them for two or three communications sessions, each of which began with a telephone call: "I'm going on the air. Turn yours on and search..."

After we finished the courses, Yura and I got jobs at the Moscow radio board for the retransmission of theatrical broadcasts and broadcasts from conferences and congresses. That was a wonderful time. We were always at the center of events.

In 7 years Yura finished secondary school without regularly attending lectures. And he "rose" from his student's bench (he studied in the correspondence division) only after almost a quarter of a century, when he was already a recognized authority in the field of automation and radar equipment. "Work comes first," Babakin always said.

M. Raykov, designer.

During the war, Babakin worked on the development of a special remote control system.

After the testing of atomic weapons by the Americans, Babakin was enlisted to work on the creation of an air defense system. Someone already saw a third world war coming from across the ocean. Actually, even one plane with an atomic bomb could cause much more damage than a thousand planes could have done before...

It was about that time that Georgiy Nikolayevich Babakin and Sergey Pavlovich Korolev met for the first time. After studying the plan for the antiaircraft control system, Korolev said, "He has the spark of genius!"

And although the plan remained just a plan, Korolev stored this meeting somewhere in his memory.

And this played no minor role in Babakin's later destiny.

One time we were kicking around the idea of converting Babakin's design office into a branch of S.P. Korolev's Experimental Design Office. This meant that Babakin would be given "deep space"; that is, the development of a station for flights to the Moon, Mars and Venus. Sergey Pavlovich was categorically against such an organizational rearrangement. He thought that a branch was some sort of dependent organization that was to a certain degree devoid of independence and, therefore, responsibility.

And so Korolev went to Babakin's people. Several of his coworkers brought out a batch of plans for the lunar and Venusian stations. With the simplicity of explication that was inherent with him, Korolev told about the difficulties of investigating the planets of the Solar System and showed, using the drawings that had been presented, possible versions of interplanetary spacecraft and complained that everything still had not been done as far as the Moon was concerned. In conclusion he said, "You're getting independent work; I'll give you all the documentation and not even keep one copy of the drawings. I believe in you and vouched for you. This work is truly ineteresting and creative."

And, not even having finished the sentence, he turned to Babakin: "Georgiy Nikolayevich, everything needs to be inspected carefully, and retouch what you need to. We'll send our suggestions to you in a few days. In general, finish things off. If you need it, of course, we will help."

Babakin answered, in his own manner, "Everything will be all right, Sergey Pavlovich."

B. Raushenbakh, USSR Academy of Sciences' corresponding member, Lenin Prize laureate.

Sergey Pavlovich Korolev was an unusually expansive man. He, if one can say it this way, gave away his own fields. I can name several prominent designers who were discovered by him. Georgiy Nikolayevich Babakin was one of them. Sergey Pavlovich always treated these people with a rare degree of benevolence. Once having given them a subject, he never again, under any circumstances, spoke of his own participation in the matter, even when the

subsequent successes were great. On the contrary: he always said, "They, they," and continued to help them unobtrusively, sometimes even from a distance

Babakin tried to grasp the new subject matter quickly. I remember when he visited the Center for Long-Range Space Communications for the first time. He was amazed by the gigantic size of the antenna, which he at first ascended in an elevator and then clambered up on an almost vertical staircase that resembled a ship's ladder. The long ranks of cabinets filled with electronic equipment astounded him. What he saw raised an undescribable delight in him--he was burning up with enthusiasm.

And then, when it was time to report to our leaders about the results of the experiment (I was then working on the "Zond-3" station, which made it possible to photograph those parts of the Moon that cannot be seen from Earth and were not photographed by the "Luna-3"), I invited Babakin so that he could get a feel for the situation.

We arrive at the meeting. They ask who will speak. And suddenly Babakin, who could not hold back, ran up to the board and started to explain the features of the experiment to those who were present. I sat there and smiled. It was just amusing to me that instead of my official report, they were getting Babakin's unofficial report, even on matters that they generally had no business being concerned with.

Why did this happen? Simply that he, having seen the equipment, understood everything and investigated everything, so that everything immediately became clear to him. So clear that he, himself, did not notice how he was exceeding his authority and was starting to report on other people's work. Later I understood that if an event, or a conversation, or a speech excited and gripped him, he would jump out of line and share his thoughts "on the occasion." If someone else's work interested him and he studied it, that meant that it was no longer someone else's.

But the most interesting thing about this story was that none of those who were present found Babakin's speech out of place. Everyone was startled and subdued by his enthusiasm. And I was simply astonished that a man could understand such a new and far from simple business so quickly.

A. Platonov, Lenin Prize laureate.

Babakin always had a lot of ideas. If a station was already finished or almost finished, he had thoughts about altering it. Or someone came to him with another idea and "fired him up" with some suggestions. Such improvements threatened the planned deadlines. He had to force himself to stop in time. Babakin did not always succeed in doing this. Then the leaders had to intervene with him: "Better is the enemy of good." At first Georgiy Nikolayevich even complained, saying that they were holding him back. Although he did understand that it could not be any other way. And he issued an order forbidding any changes after a certain date before the completion of a project.

That was a heavy blow. And primarily to himself, because he never discriminated in favor of himself. If no one could, that meant he could not.

He knew how to carry people away and get them fired up. That meant everyone, from the leaders of a project to those doing the work. He did not bang his fist on the table or yell. He trusted his coworkers, thinking that it was sufficient to explain to people what an important assignment they were working on and they would not let him down. I remember how Babakin, "on the wing," jumped at the idea of conducting a competition in the design office. One day later an order came out:

"For the purpose of attracting inventors and innovators to solve the primary problem of reducing the weight of designs while preserving the reliability, quality and technological properties of an item, I order that:
1. There be a competition to reduce the weight of items in this enterprise.
2. There be a bonus system in this enterprise that provides for the payment of an award in the sum of ... rubles for the removal of each kilogram of weight from the landing stage and ... rubles for the removal of each kilogram of weight from the return rocket."

It was determined that each "kilogram" removed from the rocket making the return from the Moon to Earth costs "more."

They sometimes say of Georgiy Nikolayevich, "He had the talents of a genius." Possibly. Except that he confirmed his talent with a titanic amount of work.

V. Arkhipenko, engineer.

One of the stations had to be sent to Baykonur in order to be prepared for launching. Testing of all the spacecraft's assemblies had been completed at the plant, and the only testing that was being done was of a single instrument that was intended for a special additional program. And suddenly the chief calls me: "Until the tests are completed, you must write in all the documents that you are against sending the station."

I was taken aback. I started to explain that I had no doubts about the successful completion of the tests and it was better to prepare the station for the launch ahead of time. The responsible leader refused my suggestion.

There was nothing to do but wait and lose valuable time. But it would have been far better to do it differently: prepare the station for the flight at the cosmodrome and, you see, the results of the tests will arrive in time.

I could not restrain myself, but went to Babakin, knowing that he always supported bold ideas.

"We are now in agreement," Georgiy Nikolayevich said confidently. He called my chief and told him about his reasons which--naturally--coincided with mine. He then added, "I have no doubts that everything will be all right. At the end we will do one or two resolderings if they're needed. The only problem," Babakin winked at me, "is your representative! For some reason, he's

against it, but I don't know why. He wants to object to sending it. What, what? Oh. You will give him instructions to agree with us? That's good. Thank you. I never doubted that you would understand us."

B. Mikhaylov, designer.

Conversations with Academicians M.V. Keldysh and A.P. Vinogradov convinced G.I. Babakin of the scientific necessity of speeding up the solution of the problem of delivering lunar soil to Earth. Of course, his limitless faith in the possibilities of automatic stations played a definite role in this.

His closest assistants found out about this very prosaically. He called us into a meeting. The chief was brief and got down to business almost immediately: "Samples of lunar soil need to be delivered to Earth."

Georgiy Nikolayevich later acknowledged that he was very disturbed that day. Would his main assistants support him? If so, then he, of course, would convince "the brass." If not, the station would not be built.

Yu. Surkov, doctor of physical and mathematical sciences, Lenin Prize laureate.

The news that a strange firm would be included in the investigations of the Moon and the planets puzzled us somewhat. Until that time we had worked with Sergey Pavlovich Korolev's Experimental Design Office. But even the very first meeting with the new organization dispelled all doubts. Having paid them a visit, we felt that the firm had had a vast amount of experience and that the collective had excellent qualifications.

I have had to deal with many leaders of technical organizations, but I only rarely encountered among them people who greeted scientific problems with interest and tried to investigate them thoroughly. Georgiy Nikolayevich stood out on the good side. He tried to understand what scientific problems we wanted to solve and wondered how he could help.

"We have enough people," he loved to say. "What do you require of us?"

That was probably one of the reasons that M.V. Keldysh, the president of the Academy of Sciences, had such kindly feelings toward Babakin.

The basic goal in studying the Moon at that stage was the investigation of lunar matter. We have achieved that result.

Lunar soil is now being studied in many countries, with half of them studying soil delivered by the "Luna-16."

A. Kolesov, Hero of Socialist Labor, Lenin Prize laureate.

We knew each other for many years. In the later years we were united by common work in the field of, shall we say, space.

Georgiy Nikolayevich understood the problems and goals of radio communications very accurately. I would even say that he was a "godsend" as a radio man.

And he delved into our work very deeply. It would be wrong of me to say that he delved even deeper than was necessary. But he never interfered with me at all, because he never lost his sense of benevolence. It impressed me that his thoughts always revolved around his work, wherever I met him, at the design office or on vacation. He always wished to consult, to find out the opinion of a stranger. I worked with Korolev for many years and knew him well. I called him "Sergey" and he called me by my first name. We were comrades. I called Babakin by his first name and patronymic. But if there always needed to be a reason for a meeting with Korolev, none whatsoever was needed for a meeting with Babakin. One frequently came up during the meeting itself.

Sometimes, having run into some unresolved problem, he suddenly appeared at my country house on a Sunday. We walked in the woods and frequently came up with a successful solution together. We covered quite a few tens of kilometers when we were working on the television system for the first lunar station.

P. Fedyakin.

The ability to control the lunar rover did not come about immediately. And the fact that we still mastered this difficult matter quite quickly is to Babakin's great credit. He was benevolent toward us and--this is especially important--he had confidence in us. When the lunar station was finally on the Moon, I remember how we entered a crater for the first time. Accidentally and unexpectedly, and we lost our heads. The search for the needed solution dragged on. I will not hide from you that we felt, as they say, as if a sizeable number of particularly impatient guests had gathered in our room and were breathing down the backs of our necks. This hung over us, and it became very difficult to think.

Do not think that I am against advice. Intelligent advice given at the proper time, of course, makes life easier. But that is a special case. Almost every driver has a great deal of driving experience. And he considers it his right to give advice, finding his advice, of course, to be better than his comrade's advice. And so you have a situation where one person says, "Go forward," and another says, "Turn first," and a third...you get the idea. You listen to them, your head is spinning, and you say nothing to them. Their advice is from the soul. It is sincere.

And then Georgiy Nikolayevich, who all the time had kept quiet and just listened, suddenly said: "I'm asking everyone to leave the room. Yes, yes, he's made his own decision, having noticed that someone didn't even move from his place, having apparently assumed that this does not concern him. Everyone, without exception. I'll go, too. The crew is well trained, and we have no grounds for not having confidence in them. It will take care of itself, and this hour will pass sooner or later, and it's not essential. I ask you!" He put his arm around the shoulders of the last person remaining in the room, propelled him out ahead of himself and left, closing the door firmly behind him.

And in a few minutes the lunar station started rolling away.

M. Konstantinov, doctor of technical sciences, State Prize laureate.

The chief had an extraordinarily sharp mind. One time, someone suggested that he choose from several designs. He immediately selected the optimum one, which then went into series production. It was difficult to assume that he had had time to weigh all the "pros" and "cons" and work it out in his mind. The fact of the matter lies elsewhere. Erudition, multiplied by intuition. And who knows which was the greater?

He had a special attitude toward theoreticians. He thought that they gave birth to ideas. And that was the main thing. Their subsequent realization was a simpler matter, even though it could take years. This approach guaranteed, I would say, the spasmodic development of interplanetary space technology. One had the feeling that Babakin was not looking at this year's calendar, but one that was 10 years ahead.

His ability to trust people helped him live "for tomorrow." He never punished anyone, but the most terrible thing was thought to be to betray his trust. And if an idea were to be suggested, it had to be reliable and "100 percent."

I recall that we were working on the "Venera" stations and a special thermal regulation system was proposed. Many specialists objected to it. Babakin believed and, moreover, said that we were thinking about a descent vehicle that would enter the dense layers of the atmosphere.

And now we are at the Center for Long-Range Space Communication in Yevpatoriya. The "Venera-4" is millions of kilometers from Earth. The end is near. The vehicle is entering the dense layers of Venus's atmosphere. Everyone is congratulating Babakin. This, of course, is a great victory. And the operator announces clearly, "Here's a signal from the descent vehicle." That, is, the "Venera-4" lives! Everyone is bustling around. Babakin says to me, "Quick, we need to interpret the telemetry."

The descent vehicle was designed for a pressure of slightly more than 10 atmospheres. The signal from it ceased when the pressure around it reached 18 atmospheres. Scientists had no idea at that time that the pressure on Venus's surface is 100 atmospheres and that the temperature is about 500°! The "Venera-4" solved part of the mystery.

There was an entirely different problem involved in the investigation of Mars. That planet's atmosphere is, on the contrary, very rarefied (only five-thousandths of Earth's). How could we slow down the descent vehicle so that it would not crash? And could we still use a parachute? We thought it would be something like that. But, as they say, the chief has the last word. So one day we were riding in a car. I toss at him the idea about the parachute. He began to argue. Then he suddenly stopped and thought, and in 5 minutes the car had arrived at a special institute that worked with parachutes.

He lived for his work and did not conceive of himself away from it. Even his hobby had some relationship to technology. He loved to tinker with automobiles. On Sundays he rummaged around in his own Moskvich and willingly

helped his friends. And, if you like, he was also a professional in his enthusiasm. He could determine what was wrong with a motor just by listening to it.

K. Al'tov, designer.

Babakin was an inveterate automobile lover. He had all kinds of Moskviches, beginning with the antediluvian "401."

He drove masterfully. He was a careful driver. He was well oriented in the streets of the city and merged smoothly with the traffic flow. But sometimes it was if some thread that attached him to the "green wave" had broken. His gaze became tenacious, his hands gripped the steering wheel firmly, and suddenly he was driving as fast as he could. The distance to the automobile rushing along in front shortened quickly. What it was about a car that touched some vein of pride in Babakin, no one knew. Possibly he himself could not explain why, obeying some "inner voice," he thrust ahead so stubbornly.

Maneuvering between vehicles and finding shortcuts, Babakin finally went around the car he was chasing. Then, with a solemn countenance, he waved his hand at the "vanquished opponent" and calmed down immediately. His car again merged with the general flow.

His license alone could tell objectively about the passionate nature of its owner.

His lightning speed in making decisions, the absence of fear, and his youthful expansiveness, which lasted until the last days of his life, made him unpredictable.

N. Babakin, candidate of technical sciences.

The first time we lived in a large communal apartment--for 56 people! We had a room. I remember that my father was then studying at the institute, in the correspondence division. Naturally, he could only study independently at night. Sometimes I woke up early in the morning and saw that he had fallen asleep right at his desk. Then he was frequently working nights. This caused him some kind of chronic lack of sleep. True, he found a way to deal with the fatigue. He could sleep in absolutely any situation when, in his opinion, there was no need to be awake: in a car, at a boring meeting. And he opened his eyes precisely by the clock.

It was sometimes even difficult to understand why he deprived himself of rest. For example, he was interested in French. And he devoted himself to it in his meager spare time.

Technology meant much in his life, but not everything. He loved animals. And although we kept fish at home for many years, his secret passion was dogs and horses. He was an excellent horseman (that remained from his service in the army), so he tried to drop in at the hippodrome whenever he could.

He loved bicycling. I remember how, two days before his death, on a Sunday, we joined him in the woods, riding bicycles. He was coughing. I began to talk him out of it. Lie down for a while, get some medical attention. He said, "I'm very tired...I'll rest a little while today..."

I said goodbye and did not know that I was saying goodbye forever. He left from his country house to work anyway, but on the road he felt bad and returned home.

He died in his study at home.

V. Lebedev, engineer-designer.

We frequently talked about Georgiy Nikolayevich's ability to work, both during his life and after it. In all, he headed our design office for about seven years, but during this time the first landing was made on the Moon, the first artificial Moon satellite was launched, the first landing was made on Venus, the first automatic station delivered soil from the Moon, the first lunar station moved across the Moon, and a pennant with the USSR's coat of arms was first delivered to Mars. That was a lot. But what else did he have time to do?

It was August 1971, and I was vacationing with friends, traveling by canoe along the rivers of Archangelsk Oblast. The trip ended, and we were sitting in a small building at an airfield, waiting for a plane. We were thinking about the trip and joking. The weather made us happy: the pure northern Sun was shining, all around us it was green, and we were enjoying the warmth and the light. Files of newspapers lay on the table, and my comrade was looking through them--it had been more than two weeks since we had seen one. Suddenly he said quietly: "Babakin died..." We were stunned. This seemed strange and incompatible with the way everything had been when we left. Georgiy Nikolayevich looked, as always, energetic and was talking about future plans. This was so incompatible that everything that surrounded us: flowering nature full of life, the flushed faces of friends. But the lines in the newspaper, which each of us read personally with astonishment and disbelief, spoke of the death of Chief Designer Georgiy Nikolayevich Babakin.

11746
CSO: 1866/44

EULOGY NOTES USTINOV'S CONTRIBUTION TO SPACE PROGRAM

Moscow KRASNAYA ZVEZDA in Russian 24 Dec 84 p 2

[Article by V. Bakhirev, USSR minister of machine building]

[Abstract] The article is a eulogy to Marshal of the Soviet Union Dmitriy Fedorovich Ustinov, published on the day following his funeral.

The author praises Ustinov's contribution, as USSR people's commissar of armaments, to the victory over fascist Germany, and to the strengthening of the country's economy and defense in the postwar period, during which Ustinov served as minister of the defense industry as well as minister of defense. Following are excerpts of the eulogy:

"I had the privilege of knowing Dmitriy Fedorovich closely, and of working with him for many years. I remember the times he came to the Kovrovskiy plant (its workers always nominated him as their deputy to the Russian Federation's Supreme Soviet), and to other enterprises. Heading up key sectors of state construction and the economy, he skillfully coordinated and directed the work of scientific institutions, design bureaus and industrial enterprises...

"The successes of the Soviet Union in the exploration of space are linked with the name of Dmitriy Fedorovich Ustinov. Speaking at the 21st Congress of the Communist Party of the Soviet Union on 4 February 1959, he said that the development of rockets and satellites required the solution of a number of serious problems in the field of the designing, technology and organization of production of new materials, and also of many complex, accurate instruments and ground equipment of various types. One of the chief problems was to master the production of powerful rocket engines, and of special fuels and heat-resistant materials for them. Entirely new processes were developed for their production. Space technology, beginning with small Earth satellites and ending with sophisticated space systems and complexes, required closely tying together the achievements of many areas of scientific-technical progress."

FTD/SNAP
CSO: 1866/67

MILITARIZATION OF SPACE ACTIVITY IN UNITED STATES

Moscow POLITICHESKOYE SAMOOBRAZOVANIYE in Russian No 6, Jun 84 pp 115-120

[Article by O. Mikhaylov]

[Text] The militaristic, aggressive policy of the Reagan administration is causing increasing concern and alarm throughout the world. There is more than adequate basis for this. The reactionary ruling circles of the United States, hoping to achieve a strategic advantage over the USSR, have unleashed an arms race which is unprecedented in scale and rate. They intend to transform space into a "springboard" of aggression and even today are accelerating the development of new systems for conducting military operations in space and from space. This is indicated, in particular, by the March (1983) speech by the American president on "space wars," his directive No 119, dated 6 January 1984 on the development of technology in this field and the formulation of specific plans for the development and use of space armaments by the Pentagon.

During the last decade the development of American cosmonautics has increasingly been subordinate to the expansionistic designs of the American militarists; it is being transformed by them into a new direction in the arms race. Not only the military, but also civilian departments in the United States, especially NASA (National Aeronautics and Space Administration), are being increasingly drawn into the orbit of the space aspirations of the Pentagon. For well-known reasons the contribution of NASA to the implementation of military programs is hushed-up or belittled. But even according to data published by the United States General Accounting Office, the expenditures of NASA on military space research are not less than one-third of its budget.

An example of what one American senator has called the "militarization of NASA," is the recent shifts in its leadership. For example, H. Mark, a former Secretary of the Air Force in the administration of J. Carter, was designated first deputy administrator of NASA. Since 1981 the direction of the "Space Shuttle" program has been assigned to General J. Abrahamson, who for 15 years was engaged in military-space planning. The Jet Propulsion Laboratory at the California Institute of Technology, having the status of a NASA scientific research center, since 1982 has been headed by General L. Allen, who earlier held the post of chief of staff USAF. But this is only the visible peak of the militaristic iceberg, more and more fettering the civilian direction of NASA activity.

With a considerably lessening number of civilian personnel at the administration headquarters and its space centers, since the beginning of the 1980's there has been an intensified influx of people in military uniform. At the same time the possibilities have been expanded for the transfer of experience and results of NASA research to the Department of Defense, the subsidization of military space programs through the budget of the administration. The multiuse "Space Shuttle" transport spaceships have been developed in accordance with the technical specifications of the Pentagon. With respect to their operation, NASA in actuality has been allocated the role of a "transport agency" of the military departments.

With the expansion of NASA participation in military programs its research is undergoing a reorientation, as well as development work in a direction necessary for the American militarists. As a result, more than 75% of the NASA budget, not counting its secret projects, can be used directly or indirectly for financing different types of activity of a military character. The tendency to a revamping of civilian space activity in the United States and the open subordination of this organization to the interests of the Pentagon is becoming increasingly obvious.

The major industrial corporations in the United States are accordingly now reorganizing their space activity to meet the growing military orders. Striving to assure themselves a greater part of the future contracts for promising space systems, the military-industrial companies are even outpacing Pentagon orders. For example, the Boeing, Northrop and Rockwell International corporations, without awaiting the receipt of federal orders, have pooled their financial resources for developing means for precise guidance of cruise missiles using the Navstar satellite navigation system. They regard civilian space activity as increasingly less promising and it is being considerably reduced.

The movements of personnel between corporations, the Pentagon and NASA in the 1970's favored the strengthening of formal and informal ties within the military-industrial group interested in intensifying the American militarization of space activity. Between 1970 and 1979 at least 1,942 persons switched between the Pentagon, NASA and the eight largest corporations receiving 25% of all the military contracts and 36% of NASA orders. J. Beggs, the present administrator of NASA, between 1974 and his designation to this post, was vice president of General Dynamics, devoted to the aerospace industry. One of the former administrators of NASA, J. Fletcher, headed a specially named group for developing long-range projects for laser and beam armaments.

With the increase in the generous financial injections from the American administration the economic basis of the American military-industrial complex is being rapidly strengthened. Its possibilities and methods for pressuring American legislators for approving increasingly more profitable military space projects are also expanding.

The use of American supposedly civilian space systems for military, reconnaissance purposes is appreciably intensifying. In particular, it has been reported in the western press that American Landsat satellites are being employed in surveying military targets in the territory of the Chinese People's

Republic. The Soviet press has told of use of the Marisat satellite communication system by the first secretary of the American embassy, R. Osborne, detained in Moscow on 7 March 1983 when transmitting espionage information. More than one-third of the Pentagon's distant communications are sent via channels leased by the Pentagon in commercial satellite systems. Presidential directive No 37 (1978) provided for a further broadening of the use of civilian space systems by the Pentagon and reconnaissance services. The special reoutfitting of space satellite systems for military purposes is already taking place. A similar reoutfitting has been planned for meteorological systems as well. Methods are being studied for supplying civilian satellites with intelligence-collecting instruments. These and other measures provided for in the directive have on an unprecedented scale broadened the real scales of American military preparations in the space arena.

From the very beginning of the space era the Soviet Union has made every effort not to allow the militarization of space unleashed by the United States and its NATO allies. In 1958 the USSR introduced a motion at the UN calling for the banning of the use of space for military purposes and disallowing military advantages in this arena for any country. The United States and its allies refused to accept this proposal.

During recent years, due to the insistent efforts of the USSR and other socialist states, a number of international agreements were nevertheless concluded restricting the militarization of space. In 1963 an agreement on the banning of testing of nuclear weapons in the atmosphere, in space and underwater was concluded. In 1967 an agreement on the principles of activity of states on exploration and use of space, including the moon and other celestial bodies, was concluded. This treaty, which includes a ban on launching any objects with nuclear weapons or any other types of weapons of mass destruction into orbit, was signed by about 100 countries. In 1977 a convention on the banning of military or any other hostile use of means affecting the environment, including circumterrestrial space, was concluded on the initiative of the USSR. In August 1981 the Soviet Union presented a draft treaty on the banning of placement of weapons of any type in space for consideration of the 36th session of the UN General Assembly.

The international agreements which were concluded considerably restricted the ambitious plans of the Pentagon. But the resistance of the United States and its NATO allies to adoption of the majority of Soviet proposals made it impossible to ensure blocking of all channels for the militarization of space activity. Sabotaging the conclusion of all-inclusive peace treaties in the space arena, the militaristic circles of the West are speedily developing new military space systems and are attempting to achieve at least temporary strategic advantages. This is indicated by the fact that American military satellite reconnaissance, communication and navigation satellites are being developed primarily for a qualitative improvement of aggressive strategic weaponry in order to compensate for restriction on numbers imposed by the corresponding agreements.

With these very same aggressive purposes Washington in every way possible is stimulating the development of space command and reconnaissance systems. A number of operative military satellite systems and systems now in development

are intended for improvement in communication with remote stationary and mobile objects, transmission of reconnaissance information and control of tactical and strategic forces. Satellite systems with increased noise immunity and protection against nuclear explosions are being developed especially for control of tactical and strategic forces.

American artificial earth satellites (AES) are being used actively for overall and detailed photoreconnaissance, especially of the territories of socialist countries. Radioelectronic reconnaissance satellites are used in intercepting radio communications and radar radiations, making more precise determinations of the characteristics of different military objects, especially means for antimissile and antiair defense.

Since the 1970's the United States has been sharply increasing the production of special apparatus (terminals) ensuring the reception of information from military satellite systems. It is intended for installation primarily on carriers of nuclear weapons and at their launching points. Since 1978 terminals of the "Afsatcom" communication system have been supplied not only for strategic bombers and posts for control of launching of intercontinental ballistic missiles, but also fighter-bombers, points for the launching of cruise missiles and the "Pershing-2," and artillery units supplied with nuclear weapons. The "Navstar" satellite navigation system is to be put into operation beginning in 1987 for considerably increasing the accuracy of air, sea, ground and space operations. In American army units alone the initial plan calls for the use of about 6,000 backpack outfits of such a system for precise calculation of distance to targets, the correction of bombing strikes and artillery fire, the landing of troops and supplies. It is proposed that the armed forces of other NATO countries be supplied with terminals of this system with the assistance of the United States.

Mobile units in all types of armed forces, including "rapid deployment forces," are supplied primarily with satellite terminals. At the same time, the use of terminals in military operations is being worked out. Modern mobile stations for the receipt of information from meteorological satellites have been used in the military exercises "Bright Star," providing for the deployment of American tactical forces in the Egyptian desert. Such stations have been ordered for the attack units of the US Marine Corps. Provision has also been made for outfitting all attack aircraft carriers with such terminals. Thus, the objective is supplying maximum satellite servicing for the military units performing subversive, aggressive and police functions of American imperialism throughout the world.

It must be said that space systems have been used by the Pentagon since the 1960's in virtually all arenas of international tension created by imperialism, including the war in Viet Nam. American navigation, meteorological, photoreconnaissance and also communication AES were used, in particular, in supporting the unsuccessful military operation for freeing the American hostages in Teheran.

In cases of indirect intervention in conflicts the United States of America furnishes AES for supporting the aggressive military operations of its allies. The reconnaissance information collected by American satellites on

countries of the Near East has been used by Israel since the war of 1967. The possibilities of use of such information by Tel Aviv have expanded considerably since the signing of the American-Israeli "memorandum on mutual understanding in the field of strategic cooperation" and even more so with the setting up of an American-Israeli military-political committee.

The reconnaissance information from American AES supplied to English forces was used by Great Britain in planning the date of the attack on the Falkland (Malvinas) Islands, for monitoring the regions of conflict and for more precise determination of the positioning of Argentinian vessels. According to a statement by W. Ramsey, Rear Admiral USN, Great Britain owed its success in the use of missiles in this conflict to American space reconnaissance. Aboard the "Hermes" alone (the British flagship) during the period of its presence in the conflict zone an average of 800 satellite signals were processed each day. Already in the course of battles on the Falkland Islands British marines used backpack outfits for communication via American satellites.

American spy satellites and French reconnaissance aircraft were used in coordinating the movement of foreign forces in Chad on American military transport aircraft. The fact of use of satellite communication terminals in the subversive operations against Afghanistan financed by the United States is also well known.

The changes in structure of military space systems hastily prepared by the American administration are related to the on-going reexamination of American strategic doctrines and the strengthening of their aggressive capabilities. Reference is to the accelerated development of space armaments, having the purpose of undermining the approximate strategic balance existing between the USSR and the United States, in particular, the development in the United States of an antisatellite system under the program of so-called "space defense" being implemented since the mid-1970's. The antisatellite system is not for defensive goals, as Washington would like people to believe, but for the strategic aggressive purposes of the Pentagon. Its development began in 1975 when the United States already had a similar system on Johnston Island in the Pacific Ocean on the basis of a "Thor" carrier-rocket adapted for putting nuclear warheads into orbit. The present-day system is intended for secret launching of special two-stage rockets for the annihilation of satellites from outwardly ordinary F-15 fighters. The launching of antisatellite missiles in accordance with already set goals was planned in interaction with the use of strategic and other types of weapons.

The development of the antisatellite system in the United States, its testing and deployment are creating a basis for the undermining of existing international agreements, constitute an obstacle to the conclusion of new agreements and checking on adherence to these agreements. In particular, the signing of a potentially possible agreement on the banning (or restriction) of antisatellite weapons is made difficult by the small size of the mentioned antisatellite missiles, carried beneath the fuselages of F-15 fighters. The results of development of this antisatellite system and its testing already carried out can be used by the Pentagon in new antimissile defense projects, thus laying a basis for violation of the 1972 agreement on antimissile defense

systems. This agreement, incidentally, obligates the USSR and the United States not to construct, not to test and not deploy such systems in space.

Despite the mentioned agreement, the United States is developing components of new antimissile defense systems, including for space, under several programs. The plan for their development, formulated within the framework of the "High Frontier" program, provides for three "defense" lines. In the first echelon there would be 432 satellites outfitted with intercepting missiles. The second echelon would be made up of orbital battle stations with laser or beam weapons. The third echelon would have surface launchers with miniature missiles to be fired in salvos.

On 23 March 1983 R. Reagan publically called for accelerated work on the development of an antimissile defense space system. At this time he cited the need for protection against the "threats" of Soviet strategic missiles. But in the call of the president of the United States, it goes without saying, nothing was said about the continuing undermining of international agreements, the aggressive purposes of use of this system. The arguments of the Pentagon in favor of accelerated development of an antimissile defense space system, expressed in a corresponding report in early 1981, were more frank. It was noted in this report that this system can be used in damaging not only strategic missiles, but satellites as well, and also aircraft. In other words, it is directly intended for "changing the balance of power in the world" and should, according to the intentions of the transoceanic strategists, ensure the dominance of the United States in space and air space and routine support of attack operations of all types of forces.

The very same objectives are being pursued in the development of the "Space Shuttle" multiuse space transport ship, although the ruling circles of the United States are also trying to conceal its military purpose. Flights with military payloads are given priority and the percentage of these flights in the total number of launchings of the ship into orbit is increasing. The "Space Shuttle" flights are being planned for accelerating the deployment and modernization primarily of military space systems put into the orbits of large reconnaissance satellites. It is becoming an important means for the testing, collection and in-orbit servicing of promising space weapons, including an antimissile defense system. The use of the "Space Shuttle" as a carrier of different types of arms, including laser and even nuclear weapons, is also not excluded. Variants of automatic and manned maneuverable spaceships of a lesser size (known as the "Mini Shuttle," "Cruiser" and "Spaceplane") and orbital stations are being actively investigated.

In the United States it is no longer being concealed that the implementation of the recently adopted program for developing orbital stations is being coordinated with the military departments. Studies are being made of the possibilities of using the stations as reconnaissance and command points, bases for the servicing of military space vehicles, carriers of different types of weapons, etc. The abundantly financed projects of the Pentagon are extending to the creation of "military space forces" with orbital fighters and bombers, new space systems on the basis of laser, beam and other types of weapons.

The intention of the Washington political leaders to break the existing equilibrium of strategic forces by means of the militarization of space is not only a provocation against the Soviet Union which will last for decades ahead. It is a new, still more dangerous turn in the arms race which is a threat to all mankind, bringing it ever closer to a nuclear catastrophe. However, those who nurture plans for "star wars" forget the most important thing: the inevitable reaction of the USSR to the implementation of their ambitious intentions. It goes without saying that the Soviet Union will not stand by idly as basic changes occur in the strategic situation being brought about by Washington in the space arena. Soviet leaders have repeatedly warned that under no circumstances would they allow military superiority over the USSR and the other countries of socialist cooperation. The United States will not acquire such superiority even if it puts its new weapons into space.

In the present-day circumstances the adventurist policy of the aggressive circles in the United States is being opposed by the sober and carefully weighed peace-loving policy of the USSR corresponding to the interests of all mankind. Soviet peace initiatives have been directed to the prevention of a transfer of the arms race into space and the maintenance of peace on the planet.

In 1984, at the disarmament conference held in Geneva, the USSR as a working document distributed a draft treaty on the complete banning of force in space and from space in the direction of the earth. The Soviet Union also presented this draft at the 38th session of the UN General Assembly.

The USSR is ready in the most radical fashion to solve the problem of antisatellite weapons -- to make an agreement on eliminating already existing antisatellite systems and banning the development of new ones. In addition to these proposals, the Soviet leadership has made a decision of exceptional importance: the USSR has assumed the obligation of not being the first to put any type of antisatellite weaponry into space, that is, a unilateral moratorium has been introduced on such launchings as long as other nations, including the United States, refrain from putting antisatellite weapons of any type into space.

Our country is insistently striving for an arrangement directed to banning of spread of the arms race into space.

"The Soviet Union," it says in a reply of Comrade K. U. Chernenko to a communication of American scientists, "is a resolute opponent of competition in an arms race, including in space. However, it should be understood that faced with a threat from space the Soviet Union will be forced to take measures for the reliable assurance of its safety. Calculations that a road to military supremacy can be laid through space are based on illusions. However, others do not want to desist from such calculations and this is fraught with exceedingly dangerous consequences. For the time being it is not too late to block such a course of events; this is the direct obligation of responsible national leaders, scientists and all those who are really concerned with the future of mankind" (PRAVDA, 20 May 1984).

The American plans for the militarization of space are causing a justifiable indignation in peaceful society. People throughout the world are now demanding a turn-around in the development of international affairs: safeguarding of the planet against the new danger, stopping of the arms race and a beginning of a reduction in arms, without breaking agreements, as Washington is doing, but instead strengthening them, rigidly adhering to and broadening them. Now this problem is becoming one of the most important in the struggle for peace and disarmament, for restraining the aggressive forces of the imperialistic states and preserving life on the earth.

5303
CSO: 1866/180

LAUNCH TABLE

LIST OF RECENT SOVIET SPACE LAUNCHES

Moscow TASS in English or Russian various dates

[Summary]

Date	Designation	Orbital Parameters			
		Apogee	Perigee	Period	Inclination
16 Jan 85	Cosmos-1617 -- Cosmos-1622	1,438 km	1,400 km	114 min	82.6°
		(Six satellites launched by single booster)			
16 Jan 85	Cosmos-1623	405 km	216 km	90.4 min	70°
16 Jan 85	Molniya-3	40,653 km	646 km	12 hrs 16 min	62.9°
		(Communications satellite for long-distance telephone, telegraph & radio communications and transmission of USSR Central Television to stations in the "Orbita" network)			
17 Jan 85	Cosmos-1624	825 km	787 km	100.8 min	74°
18 Jan 85	Gorizont	35,096 km	--	23 hrs 21 min	1.5°
		(Communications satellite for further development of systems of communication and TV broadcasting; near-stationary, circular orbit)			
23 Jan 85	Cosmos-1625	411 km	114 km	89.7 min	65°
24 Jan 85	Cosmos 1626	677 km	643 km	97.7 min	82.5°

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14 MARCH 85